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DRAFT
FEASIBILITY STUDY WORK PLAN

MASSACHUSETTS MILITARY RESERVATION
CAPE COD, MASSACHUSETTS

Prepared for:

NATIONAL GUARD BUREAU
ARLINGTON, VIRGINIA

And

MASSACHUSETTS ARMY NATIONAL GUARD
CAMP EDWARDS, MASSACHUSETTS

Pursuant to:

THE UNITED STATES ENVIRONMENTAL PROTECTION AGENCY, REGION I
Administrative Order SDWA 1-2000-0014

Prepared By:

Ogden Environmental and Energy Services, Inc.
Supervising Contractor
Westford, Massachusetts

7 April 2000

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DISCLAIMER:

This document has been prepared pursuant to a government administrative order (U.S. EPA Region I SDWA Docket No. 1-2000-0014) and is subject to approval by the U.S. Environmental Protection Agency. The opinions, findings, and conclusions expressed are those of the authors and not necessarily those of the Environmental Protection Agency.

1.0 INTRODUCTION

1.1 Background

The United States Environmental Protection Agency (USEPA) Region I issued an Administrative Order (AO) to the National Guard Bureau (NGB) and Massachusetts Army National Guard (MAARNG) on 07 January 2000. This AO is informally referred to as AO#3 and is identified by USEPA as EPA Docket No. SDWA-1-2000-0014. AO#3 specifies a series of Rapid Response Actions (RRAs) and Remedial Actions be implemented to be protective of groundwater at the Massachusetts Military Reservation (MMR) Camp Edwards Training Site. The RRA requirement of AO#3 is being implemented as documented in the Draft Work Plan, Rapid Response Action and Draft Release Abatement Measure Plan (Ogden, 2000a). The requirement to plan for Remedial Actions is addressed in this document.

This Feasibility Study Work Plan (FSWP) is the first in a series of deliverables that are required to comply with the AO#3 Statement of Work (SOW) for completing Feasibility Study (FS), Remedial Design (RD) and Remedial Action (RA) activities outlined in Appendix B. AO#3 identifies five Areas of Concern (AOCs) where an FS shall be conducted for soil and/or groundwater remediation. The AOCs and media identified in AO#3 to be evaluated are listed below. Additional AOCs and/or media may be identified in the future as data becomes available from ongoing and planned site characterization activities.

- Demolition Area 1 (Demo 1) – soil and groundwater
- Central Impact Area – groundwater
- Southeast Corner of Ranges – soil and groundwater
- Training Ranges and Impact Area – unexploded ordnance (UXO)
- Chemical Spill (CS) 19 – soil and groundwater

Chemical Spill (CS)-19 is currently being addressed by others as part of the Installation Restoration Program (IRP) and therefore will not be included in this FSWP. The geographical locations of each AOC are shown on Figure 1-1.

1.2 Objectives

The overall objective of AO#3 - Appendix B is to evaluate potential remedial alternatives for RA at AOCs in the Training Ranges and Impact Area at Camp Edwards to provide a basis for the selection and implementation of appropriate Remedial Actions that are protective of groundwater.

The objectives of the FS component of AO#3 are to:

- Review applicability of various remedial technologies, including innovative technologies, to determine whether they are technically appropriate remedies.
- Identify Remedial Action Objectives.
- Evaluate each alternative in the short and long term to determine whether it is effective, implementable, and cost effective.
- Evaluate each of the potentially effective remedial alternatives or combination of alternatives through a detailed and comparative analysis.

The FS also typically includes conceptual design elements, engineering analyses, cost analyses, and an analysis of time frames for the achievement of preliminary remediation goals.

The overall objective of the FSWP is to provide the foundation, approach and schedule for the subsequent submittals required to complete the FS, RD and RA components for the AOCs.

1.3 Report Organization

This FSWP is intended to meet the requirements of USEPA Region I Administrative Order, EPA Docket No. SDWA-1-2000-00014, Appendix B requirements for the NGB and the MAARNG to prepare and submit a FSWP. The work plan contains nine sections that are summarized below.

Section 1.0 introduces the requirements of AO#3 – Appendix B, its objectives and the topics the work plan addresses. Section 1.0 also describes the overall remediation process, presents contaminants of potential concern and preliminary remediation goals, and provides a brief background of MMR.

Section 2.0 summarizes previous, ongoing and currently planned investigations for each AOC. This section also describes the AOC history, use and physical conditions.

Section 3.0 identifies the additional investigations planned to characterize the nature and extent of contamination present at each AOC. Section 3.0 also presents a preliminary site conceptual model for the Training Ranges and Impact Area that considers known and suspected sources of contamination, types of contaminants and affected media, known and potential routes of migration and known and potential human and environmental receptors.

Section 4.0 outlines the FS process and objectives.

Section 5.0 identifies potentially applicable remedial technologies and any technology specific data requirements and describes how the data requirements will be achieved.

Section 6.0 provides the details and references that comprise the Project Operations Plan (POP) and identifies the FS organization and management team. A field sampling plan for additional soil investigations at Demo 1 is also presented in this section.

Section 7.0 describes the Long Term Monitoring Plan to monitor impacted media to determine the potential changes in the nature and extent of the contamination and to provide data to evaluate seasonal variability, climatological influence, fate and transport, and background levels for contaminants identified at each AOC.

Section 8.0 provides a detailed schedule of events that depicts the overall process to address each AOC in accordance with AO#3, Appendix B.

Section 9.0 lists the cited references.

Figures and tables are presented at the end of this document.

1.4 Remediation Process

Figure 1-2 presents the overall remediation process that will be used to ultimately select and implement appropriate Remedial Actions at the AOCs. The AOCs are at different stages within this process; therefore each will have a unique execution timeline. Figure 1-3 identifies the tasks, objectives and associated documents for each of the components of the remediation process.

Scoping is the planning phase for the overall remediation process. This includes collecting and analyzing existing data, identifying potential AOCs and operable units, determining preliminary remedial response objectives and preparation of project plans. The scoping activities are continuously updated as new information and data become available. The initial scoping activities have been completed for site characterization activities under the Impact Area Groundwater Study (IAGS) Program. As new requirements are identified site specific investigation work plans are developed under the IAGS. This FSWP is the scoping document for the FS and also updates site characterization planning information where appropriate.

Site characterization includes conducting field investigations, defining the nature and extent of contamination, and establishing risk-based remediation goals. The AOCs are currently at different stages of the remediation process. Site characterization work is nearly complete for Demo 1, approximately at the midpoint for the Central Impact Area and just getting underway for the Southeast Corner of the Ranges and UXO. Site characterization is currently being conducted under the IAGS and will be documented in the various site characterization reports for each AOC.

The development and screening of alternatives involves identifying potential remediation technologies, screening the technologies, and assembling the technologies into alternatives. Identification of potential technologies and preliminary screening is typically started while site characterization activities are still in progress. As information is generated, it flows back and forth between site characterization and development and screening of alternative activities in an iterative fashion. This process ensures that the required data are collected to properly evaluate alternatives. A preliminary evaluation of remediation technologies for soil and groundwater has been conducted for Demo 1 (Ogden, 2000h). Since contaminants at the AOCs are similar, this evaluation provides appropriate information for all AOCs. As site characterization is completed, the evaluation will be updated and documented in the Development and Initial Screening of Alternatives Report.

Post-screening investigations can include literature searches to obtain additional data on treatment technologies, bench and/or pilot scale treatability tests, and collection of additional field data to further assess the characteristics of an AOC. The need for post-screening investigations is evaluated throughout the characterization and screening process and will be determined after completion of the Development and Initial Screening of Alternatives Report. These investigations, if necessary, will be delineated in a Post-Screening Investigation Work Plan. These investigations provide critical data required to properly evaluate potential remedial alternatives, therefore, they are conducted prior to completing the detailed analysis of alternatives. The results of any post-screening investigations will be reported in the FS Report or a separate Post-Screening Investigation Report.

The detailed analysis of alternatives involves further refining alternatives as necessary, analyzing the alternatives against specific criteria, and comparing the alternatives to each other. This analysis and comparison provide the information needed to select an appropriate remedy. The FS Report documents the evaluation.

The Remedy Selection Plan documents the proposed remedial action alternative. The plan summarizes the description, analysis and comparison of all alternatives evaluated in the FS and describes the rationale for selecting the proposed remedial alternative. This plan will be submitted to solicit public comment on the proposed remedy after completion of the FS. The Remedy Selection Plan is not required by AO#3, but will be prepared to facilitate public participation in the remedy selection process.

The decision document officially selects the remedy. This document will summarize the site characterization and FS data and provide a detailed description of the components and performance objectives of the selected remedy. The Decision Document will be prepared by the Guard upon incorporation of agency and public comments on the Remedy Selection Plan.

RD involves preparation of detailed plans and specifications that will be used implement the selected remedy. RA is the execution of the selected remedy. The anticipated activities to be conducted and documents to be submitted for the RD and RA are identified in Section 8.3.

1.5 Contaminants of Potential Concern

AO#3 identified contaminants of potential concern (COPCs) for the AOCs and affected media based on existing data. The following subsections present the currently identified COPCs and discuss how the preliminary remediation goals (PRGs) will be established for soil and groundwater at each of the AOCs. The list of COPCs will be continuously updated as new site characterization data become available. A detailed screening of COPCs will be conducted upon completion of site characterization activities to identify all contaminants of concern for each AOC.

1.5.1 Soil

COPCs identified for soil at Demo 1 in AO#3 are hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX); octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX); 2,4-dinitrotoluene (2,4-DNT); 2,6-dinitrotoluene (2,6-DNT); 2-amino-4,6-dinitrotoluene (2A-DNT); 4-amino-2,6-dinitrotoluene (4A-DNT); di-N-Butylphthalate; and N-nitrosodiphenylamine.

No COPCs for soil were identified in AO#3 for the Central Impact Area, Southeast Corner of the Ranges or UXO. Soil contamination was identified at the Steel Lined Pit with the Southeast Corner of the Ranges AOC and is being addressed by the RRA in accordance with the Draft Work Plan, Rapid Response Action and Draft Release Abatement Measure Plan (Ogden, 2000a). COPCs for UXO will be identified based upon ongoing characterization activities.

PRGs that are protective of groundwater will be developed based on the fate and transport modeling currently being planned for Camp Edwards (Ogden, 1999d). The final contaminants of concern for an AOC will be selected based on the site characterization data and comparison to the PRGs.

1.5.2 Groundwater

Table 1-1 presents the groundwater COPCs identified in AO#3 for the AOCs and the proposed PRGs. PRGs were selected based on the most conservative risk-based standard of the Federal Maximum Contaminant Levels (MCLs), Federal Secondary MCLs (SMCLs), Massachusetts Contingency Plan (MCP) GW-1 Method 1 Standards, Federal Lifetime Health Advisory (HA), and the Drinking Water Equivalent Levels (DWELs). The feasibility of remediation to background concentrations for groundwater will be evaluated in the FS. Similar to soil, the COPCs for groundwater will be updated as new data warrant.

1.5.3 UXO

Specific COPCs have not been identified for UXO at this time. Investigations and evaluations of UXO and its potential impact to groundwater are currently underway. The activities planned are described in Section 2.4.5.

1.6 Site Description

The MMR is a 21,000-acre facility located on Cape Cod, in the towns of Bourne, Falmouth, Mashpee and Sandwich in Barnstable County, Massachusetts. The MAARNG conducts training operations at MMR under the direction of NGB. Approximately 14,000-acres of MMR constitute the Training Ranges and Impact Area. The Training Ranges and Impact Area lie directly over the Sagamore Lens, a major groundwater recharge area and the most productive part of the Cape Cod Aquifer. Groundwater flows radially in all directions from the apex of the Sagamore Lens located at the southeast corner of the Impact Area (Figure 1-1).

The AOCs are located within the Training Ranges and Impact Area and are currently being investigated as part of the ongoing IAGS Program. Results from the ongoing investigations prompted the identification of the AOCs and affected media.

The following subsections provide background information on the history of operations, land use and demographics, climate, geography, geology, hydrogeology, groundwater use, and ecological setting. This information was obtained from the Final Remedial Investigation UTES/BOMARC and BOMARC Area Fuel Spill Source Operable Units: CS-10A and CS-10B (CDM, 1997).

1.6.1 History of Operations

Military use of portions of MMR began as early as 1911; however, the majority of activity at MMR has occurred since 1935, and has included operations by the U.S. Army, U.S. Navy (USN), U.S. Coast Guard (USCG), U.S. Air Force (USAF), Massachusetts Army National Guard (MAARNG), U.S. Air National Guard (ANG), and Veterans Administration (VA).

The level of activity at MMR has varied over its operational history. The most intensive U.S. Army activity occurred during World War II (WWII) from 1940-1944 and during demobilization after the war, when large-scale motor pool activities and troop billeting took place in the center of the Cantonment Area. The USN conducted advanced naval aviation, carrier-based flight training during the last two years of WWII. The USAF maintained intensive aircraft operations from 1955 to 1970 along the flightline areas in the southeastern portion of the Cantonment Area. Airborne surveillance activities were phased out in the early 1970s.

Ongoing operations at MMR include ARNG and U.S. Army Reserve training, Air Station Cape Cod (USCG), the PAVE-PAWS missile and space vehicle tracking system (USAF), and the Massachusetts National Cemetery (VA).

1.6.2 General Land Use and Demographics

Several areas of MMR are utilized for activities such as the Otis Air Force Base Airfield and military support facilities. About 2,000 year-round residents live in a housing area operated by the USCG on MMR, which includes a chapel, a golf course, a base commissary, a medical dispensary, three public schools operated by the town of Bourne, and one private school. The MMR resident population increases by as much as several thousand people during Reserve and National Guard activities. Both year-round and seasonal residents live in towns adjacent to MMR.

Recreational land use in the area near MMR includes golfing, swimming, boating, and other water sports. Two ponds adjacent to MMR (John’s Pond and Ashumet Pond) support fishing, boating, and water skiing. Shawme Crowell State Forest and Crane Wildlife Management Area provide hunting opportunities for residents, as well as other recreational pursuits such as model plane flying. In addition, portions of MMR are opened for deer hunting by permit from the Massachusetts Division of Fisheries and Wildlife. A summer camp for young people, Camp Good News, is located east of MMR on Snake Pond.

The major agricultural land use near MMR is the cultivation of cranberries. Other agricultural uses include farming of blueberries and other fruits and vegetables. Commercial and industrial development includes service industries, sand and gravel pit operations, municipal landfills, and wastewater treatment facilities.

1.6.3 Climate

The climate at MMR is classified as humid continental. Proximity to the Atlantic Ocean has a moderating effect on temperatures, producing warmer winters and cooler summers than nearby inland areas. February is usually the coolest month of the year, with daily temperatures ranging from an average minimum of 23 degrees F to an average maximum of 38 degrees F. The warmest month is July, with average daily temperatures ranging from 63 to 78 degrees F.

Precipitation is fairly evenly distributed throughout the year, with the least rainfall typically occurring during June. Average annual rainfall is 47.8 inches. Average precipitation is 4 inches per month throughout the year, with a variation of 2 to 4.8 inches per month.

Prevailing winds are from the northwest from November to March and from the Southwest from April to October. Wind speeds vary from an average of 9 miles per hour (mph) during the summer and early autumn to an average of nearly 12 mph from late autumn through early spring. Tropical and oceanic storms occasionally cause short periods of much higher wind velocities.

1.6.4 Geography

MMR is located on two distinct types of terrain. The Cantonment Area lies on a gently southward-sloping outwash plain, with elevations ranging from 100 to 140 ft above sea level. The area to the north and west of the Cantonment Area is dotted with irregular hills and lies in the southern extent of Wisconsin Age terminal moraines. Elevations in this area range from 100 to 250 above sea level, on average. Kettle holes and depressions are found over the entire site, some of which contain water.

1.6.5 Geology

The geology of western Cape Cod is comprised of glacial sediments deposited during the retreat of the Wisconsin stage of glaciation. Three extensive sedimentary units dominate the regional geology: the Buzzards Bay Moraine (BBM), the Sandwich Moraine (SM), and the Mashpee Pitted Plain (MPP). The BBM and the SM lie along the western and northern edges of western Cape Cod, respectively. The MPP, which consists of fine to coarse-grained sands forming a broad outwash plain, lies between the two moraines. Underlying the MPP are fine-grained, glaciolacustrine sediments and basal till at the base of the unconsolidated sediments. The BBM and SM are composed of ablation till, which is unsorted material ranging from clay to boulder size that was deposited at the leading edge of two lobes of the Wisconsinian glacier at its furthest advance. These moraines form hummocky ridges.

The total thickness of unconsolidated sediments overlying bedrock varies from approximately 175 ft near the Cape Cod Canal in the northwest to approximately 325 ft at the thickest portion of the BBM, while decreasing to about 250 ft near Nantucket Sound in the south. The portion of the overburden composed of MPP outwash sediments varies in thickness from approximately 225 ft near the moraines in the north to about 80 ft near the shore of Nantucket Sound. Glacio-lacustrine sediments and till underlying the MPP generally increase in thickness as the proportion of MPP sediments decrease. Bedrock, which has been mapped as a granodiorite, lies approximately 300 ft below the ground surface (bgs).

1.6.6 Hydrogeology

The following discussion is primarily related to the MPP. Hydrologic characteristics associated with the moraines are not as well defined.

A single groundwater flow system underlies western Cape Cod, including MMR. The aquifer system is unconfined (i.e., it is in equilibrium with atmospheric pressure and is recharged by infiltration from precipitation). Surface water runoff at MMR is virtually nonexistent except on extreme slopes, due to the highly permeable nature of the sands and gravels underlying the area. The high point of the water table occurs as a groundwater mound beneath the northern portion of MMR (Figure 1-1). Groundwater flow generally radiates outward from this mound. The aquifer is bounded by the ocean on three sides, with groundwater discharging into Nantucket Sound on the south, Buzzards Bay on the west, and Cape Cod Bay on the north. The Bass River in Yarmouth forms the eastern lateral aquifer boundary.

Surface water is present on MMR in a few of the drainage swales and as ponds in kettle holes on the MPP. The kettle hole ponds are depressions of land surface below the water table. On a regional scale, these kettle hole ponds influence groundwater flow in a similar manner to large aquifer heterogeneity. The larger or deeper the pond, the greater is the effect on slope and direction of the regional water table near the pond. While horizontal groundwater flow is dominant in the aquifer system, vertical flow driven by piezometric head differences is important in areas near ponds.

The MPP consists of coarse-grained sand and gravel outwash sediments underlain by finer-grained sediments. The hydraulic conductivity of the outwash sediments can range up to 380 ft/day (E.C. Jordan 1989b). Hydraulic conductivity of the fine-grained sediments is only 2 to 10% of the outwash. Therefore, the bulk of regional groundwater flow is transmitted though the upper outwash unit, with the horizontal flow velocities ranging from 1 to 3.4 ft per day. The hydraulic gradient across MMR ranges from about 0.0014 to 0.0018 ft/ft (E.C. Jordan 1989b).

1.6.7 Groundwater Use

The primary drinking water supply for MMR comes from a groundwater supply well completed in glacial outwash (Well J) located on the base. The adjacent towns of Bourne, Falmouth, Mashpee, and Sandwich also derive their drinking water from wells, although Falmouth also has a reservoir for that purpose. The water supply wells at MMR and the surrounding towns range between 40 and 412 ft deep, with the majority of wells extending to depths of 50 to 100 ft bgs. In areas where public water supply lines are not available, residents use private wells for domestic water supplies.

1.6.8 Ecological Setting

Approximately 80% of MMR's 22,000 acres is underdeveloped land, which provides a natural habitat for wildlife. The remaining 20% of MMR has been developed to support various military needs. Forested areas on MMR occur mainly in the Training Ranges and Impact Area (Figure 1-1), and are classified as pine-oak climax forests. The cantonment and flightline areas consist of open, mowed grasslands.

2.0 CHARACTERIZATION OF AREAS OF CONCERN (AOCS)

Based upon existing data and evaluations conducted to date, the following AOCs have been identified in AO#3.

- Demolition Area I
- Central Impact Area
- Southeast Corner of the Ranges
- UXO in the Training Ranges and Impact Area
- Chemical Spill (CS)-19

Characterization is in progress and at varying stages of completion for the individual areas. Demolition Area I has been the focus of several previous investigations and therefore significant data are available to begin to evaluate the nature and extent of contamination. Response activities are ongoing in the Central Impact Area and will commence soon for the Southeast Corner of the Ranges and UXO.

A brief discussion of CS-19 is included in this document; however, this AOC is being addressed by others as part of the IRP and will not be incorporated into the FSWP at this time. Detailed information pertaining to the AOCs is provided in the following subsections.

AO#3 identified COPCs for the AOCs and affected media based on existing data. Section 1.5 identifies the current COPCs for each AOC and currently impacted media. Additional AOCs, media and/or COPCs may be identified as new site characterization data are collected.

RRAs are being conducted at areas within the Training Areas and Ranges to address localized areas of soil contamination identified in AO#3. RRAs to be conducted at an AOC are indicated below. These actions are intended to eliminate current and potential sources of contaminants to the aquifer from soils and sediments. Residual contamination, if any, will be evaluated in conjunction with other site characterization data to determine COPCs for the AOCs.

2.1 Demolition Area I

2.1.1 Description

Demolition Area 1 (Demo 1) is located north of Forestdale Road and south of the Impact Area, near the current H Range at MMR. Demo 1 includes a natural 1-acre topographic depression, or kettle hole, that is approximately 45 feet (ft) below the surrounding grade. An access road surrounds the topographic low and circumscribes a 7.4-acre area. The bottom of the topographic low is a flat, cratered area. Low areas and individual craters remain wet for most of the winter and spring. A concrete observation bunker was constructed on the north-facing slope of the south side of the topographic low, but has since been removed. Demolition activities appear to have been concentrated in the topographic low, based on historic maps and interview information. According to interview information, demolition activities in the topographic low did result in the intermittent ejection, or "kick out", of explosives and/or demolition materials from the depression into the surrounding area (USACE, 1999).

2.1.2 Physical Conditions

The depth to groundwater from the base of the kettle hole depression is approximately 40 feet below ground surface (bgs). This corresponds to an elevation of 70 feet national geodetic vertical datum (ngvd). The lithologic data for Demo 1 suggest increased clay content near the ground surface, which may contribute to ponding of surface runoff. The drilling logs for these borings indicate that clay and sand is present in the top 7 to 10 ft, which then changes to mostly sand below 10 ft. This is consistent with the visual observation of ponded water in the Demo 1 area during the wetter winter months. The deeper lithologic material in the unsaturated zone consists of very coarse sand and gravel associated with topset and foreset sedimentary facies. The horizontal hydraulic conductivity of these materials is assumed to range from 125 to 350 ft /day based on grain size analysis (Masterson et al. 1996). The ratio of the horizontal to vertical hydraulic conductivity is estimated to be 3:1. The horizontal hydraulic gradient in and around the Impact Area ranges from 0.0002 to 0.003 ft/ft. Differences in hydraulic head between wells completed in the same cluster are so small as to be immeasurable. Thus, vertical gradients in the aquifer are small except at recharge and discharge locations. Solomon et al. (1995) report horizontal hydraulic gradients of 0.004 and vertical hydraulic gradients of 0.006.

Pumping or slug tests were not performed as part of the IAGS, so estimates of the hydraulic conductivity of the aquifer were not performed.

The saturated zone ranges from 185 to 340 ft thick. The surficial material within the saturated zone exhibits a coarsening upward sequence (lacustrine, bottomset, foreset, and topset sedimentary facies) consistent with a glacial depositional environment (Masterson et al. 1996). The lithologic material varies from very coarse sand and gravel at the top of the saturated zone to silt and clay. Hydraulic conductivity decreases with distance from sediment sources. Based upon on slug and aquifer test data collected at MMR and similar hydrogeologic environments on Cape Cod, the horizontal hydraulic conductivity of the surficial sediments is estimated to range from 10 to 350 ft/day. Horizontal hydraulic conductivity data based on lithology include: fine sand and silt was 40 ft/day (a single aquifer test); fine sand ranged from 125 to 160 ft/day; fine to medium sand ranged from 180 to 200 ft/day; and fine to medium sand and gravel ranged from 220 to 270 ft/day (Masterson et al., 1996). However, no specific hydraulic conductivity or porosity data have been collected at Demo 1. A layer of till (< 5 to 20 ft thick) is present on top of bedrock. The hydraulic conductivity of the till is estimated at 1 ft/day. The bedrock layer is present at a depth of 285 to 365 ft bgs and can be considered an impermeable layer.

The chemical characteristics of the groundwater indicate an aerobic system, i.e., the presence of oxygen with a near neutral pH. The ionic strength of the groundwater is low.

2.1.3 History and Use

Past use and historical information are described in detail in the Army Corps of Engineers' Archive Search Report (USACE, 1999). The E-2 Range was constructed in 1970 at the area now known as Demo 1. Up until the mid 1970's, the E-2 Range functioned as a rifle squad attack course at that location. Ammunition used there included .30 caliber and 7.62mm rounds. From the mid 1970's to the late 1980's, the range was used for heavy demolition. Ordnance use during this period included C-4 (a mixture of RDX with a plasticizer), 2,4,6-trinitrotoluene (TNT), and other explosive charges under 40 pounds.

The following description of demolition activities appears in the Army Corps of Engineers' Archive Search Report (USACE, 1999).

Demo 1 Range was established in its current location between 1986 and 1989 as a heavy demolition site. It was used primarily for the training of explosive ordnance disposal (EOD) personnel and engineer units and for the destruction of various types of unexploded ordnance. Ordnance used at Demo 1 include explosive charges of C-4, TNT with a weight limit of 40 pounds, detonation cord, bangalore torpedoes, and claymore mines.

2.1.4 Summary of Existing Soil and Groundwater Investigations

The following is a chronology of soil and groundwater investigations performed for Demolition Area I. Additional sample collection and analyses are in progress. As such, the data results are not included in this section; however, a brief discussion of these on-going and planned activities is included Section 2.1.5.

2.1.4.1 Soil

Demo 1 was first sampled during Phase I of the IAGS. The general scope and objectives of the IAGS are documented in the Final Action Plan (ETA, 1997). However, the scope of investigations under the IAGS increased during the field implementation phase. A Field Sampling Plan for Area 12 – Demo 1 and Area 13 – Demo 2 of the Camp Edwards IAGS was finalized in November 1997 (Ogden, 1997b) and included six surface soil grids and one boring completed as a monitoring well nest. The results of the Phase 1 IAGS were presented in the Draft Completion of Work Report (Ogden, 1998a).

Boring 19 was installed in the middle of the flat crater area at the bottom of Demo 1. The unsaturated zone was sampled and the boring was completed as a monitoring well nest with a water table (MW-19S) and deep (MW-19D) monitoring well. Soil grids 12A, 12B, 12C, 12D, and 12E were located around the drill pad for boring 19. These soil grid samples were collected at the surface (0-6 inches) with the exception of 12A and 12D, which were collected 18 to 24 inches bgs. Craters were evident at these five soil grid locations. Grid 12F was added as a control grid for Demo 1. Grid 12F is located in a moderately vegetated area along the roadway leading into Demo 1. Figure 2-1 depicts sample locations and the analytical results for detected explosive compounds.

Six explosive compounds were detected in surface soil samples, including RDX, HMX and several TNT breakdown products: 2,4-DNT, 2,6-DNT, 2A-DNT, and 4A-DNT. RDX was also detected at 10-14 ft bgs in boring 19.

Twelve metals were detected at concentrations exceeding Phase I proposed background levels, most commonly manganese and copper. Acetone was detected in subsurface soil at grid 12B, and trichloroethylene (TCE) was detected in a duplicate surface soil sample (but not in the original) from boring 19. Semi-volatile organic compounds (SVOCs) were detected in the surface soil samples and duplicate. The list includes benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i,)perylene, benzo(k)fluoranthene, bis(2-ethylhexyl)phthalate, chrysene, di-n-butylphthalate, fluoranthene, ideno(1,2,3-c,d)pyrene, N-nitrosodiphenylamine, pentachlorophenol, and pyrene. Phenanthrene was also detected in the duplicate, but not in the original field sample. The pesticides/herbicides detected in surface soil included dieldrin, lindane, heptachlor epoxide, hexachlorobenzene, and 2-methyl-4-chlorophenoxyacetic acid (MCPP). All detected concentrations were very low, i.e., less than 1 milligram per kilogram (mg/kg), except for MCPP.

The Workplan for Completion of Phase I Activities (Ogden, 1998b) specified additional soil sampling within Demo 1. This plan included the installation of nine borings to a depth of 16 ft with samples collected on 1-ft intervals. If explosives were detected, then sampling was to continue to the water table with samples collected at 2-ft intervals. Prior to advancing these nine soil borings, an interim measure to obtain additional groundwater samples was documented in an Immediate Response Plan. This is discussed in greater detail in Section 2.1.4.2.

Nine borings (B-1 through B-9) were installed at the locations shown on Figure 2-1. The borings were each advanced using a down-hole magnetometer for unexploded ordnance (UXO) clearance to a depth of 12 ft. Soil samples were collected for explosives on 1-foot intervals from 3 to 16 ft bgs. Based on the results from these samples, four of these borings (B-3, B-4, B-6, and B-9) were sampled on 2-foot intervals from 16 feet to the water table, approximately 44 feet. Samples were analyzed for explosive compounds using USEPA Method 8330.

RDX, HMX, nitroglycerin (NG), and several TNT breakdown products: 2A-DNT, 4A-DNT, and 2,4-diamino-4nitrotoluene (2,4-DANT) were detected in samples from six of the nine borings (B-1 through B–6) as shown on Figure 2-1. The explosive detections were confirmed with the photo diode array (PDA) method. However, the deep soil analysis results indicate the detections of explosives are sporadic, primarily RDX, at depths generally less than 16 feet bgs (Ogden, 2000g). Nine of the 13 intervals sampled below 16 feet had no detectable concentrations of explosives.

The highest RDX concentration, 9300 micrograms per kilogram (ug/kg), was observed in boring B-6 at a depth of three to four feet bgs. The highest HMX concentration, 800 ug/kg, was observed in the same boring at the same depth. Boring B-6 had the most frequent and deepest RDX detections, extending almost to the water table at 36 feet bgs.

COPCs identified for soil at Demo 1 in AO#3 are RDX; HMX; 2,4,-DNT; 2,6,-DNT; 2A-DNT; 4A-DNT; di-N-Butylphthalate; and N-nitrosodiphenylamine. PRGs that are protective of groundwater will be developed based on the fate and transport modeling (Ogden, 1999d). The final contaminants of concern for an AOC will be selected based on a detailed evaluation and screening of all site characterization data and comparison to the PRGs.

2.1.4.2 Groundwater

One boring was completed as a monitoring well nest, MW-19, during Phase I of the IAGS. In addition and at the request of USEPA, soil boring B-9 was completed as a monitoring well (i.e., MW-73). TNT, HMX, RDX, 2A-DNT, and 4A-DNT were detected in the shallow well MW-19S at levels of 10, 44, 190, 2.3, and 4.5 ug/L, respectively. The deep well at this same location had a detectable level of RDX at 0.4 ug/L. Figure 2-2 depicts compounds detected at each location.

Based on the initial groundwater monitoring results, an Immediate Response Plan was developed for Demo 1. The Immediate Response Plan included additional sampling of the MW-19 nest; groundwater profiling at MW-31 (located 750 ft downgradient from MW-19); installation and sampling of well nests at MW-31, MW-32 and MW-33 (located approximately 2800 ft downgradient from MW-19); and validation of the MW-19 profile samples using PDA spectra.

Although the deep well at MW-19 was originally found to contain a trace level of RDX, subsequent data later refuted this finding. Three lines of evidence indicate that the deeper aquifer does not contain RDX at this location: subsequent groundwater sampling; profile sampling; and the USGS groundwater model.

The sample collected from MW-19D in March 1998 contained RDX at 0.40 ug/l. However, samples collected from MW-19D on July 17, 1998 and February 11, 1999 did not contain RDX, at a reporting limit of 0.25 ug/l. The validation of MW-19 profile samples using PDA spectra indicates that RDX at MW-19 is limited to the top 20 feet of the aquifer, which is consistent with a release to the water table from soil in the vicinity of MW-19. The earlier finding of RDX in MW-19D is also inconsistent with the current understanding of groundwater movement in the aquifer. A detailed analysis of groundwater flow and contaminant migration is presented in the United States Geological Survey (USGS) report on particle tracking (Masterson et al. 1996).

The Workplan for Completion of Phase I (Ogden, 1998b) also specified additional groundwater sampling downgradient from Demo 1. Three additional monitoring wells (MW-34, MW-35, and MW-36) were installed between MW-32/33 and MW-19 to locate the downgradient extent of contamination. The placement of these wells was based on USGS-modeled particle tracks from MW-19. Please refer to Figure 2-2 for well locations.

The compound TNT exceeded the HA of 2 ug/L during four consecutive events at a single location (MW-19S). The only other detection of TNT in groundwater at Camp Edwards occurred at MW-31S (1.2 ug/L), which is also located 750 ft downgradient of MW-19. The remaining exceedances were associated with RDX. The explosives detected in groundwater at Demo 1 are the highest observed at Camp Edwards. The maximum detected levels of RDX, HMX, and TNT were 370 ug/L, 93 ug/L, and 16 ug/L, respectively. RDX and HMX are present in groundwater from MW-31, but were not detected at MW-32 or MW-33. The results from MW-34 include RDX and HMX detects in the two upper profile samples as well as in the monitoring well MW-34M2 installed at this depth. No explosives were detected in either MW-35 or MW-36. Therefore, the maximum downgradient extent of explosives originating at Demo 1 is less than 3,000 ft. Historical groundwater data collected over the last 2 years show little fluctuation in RDX concentrations detected between sample events at MW-19 and MW-31. Concentrations of HMX and particularly TNT in the same wells have generally shown a decreasing trend over time.

Table 1-1 presents the groundwater COPCs identified in AO#3 for the AOCs and the proposed PRGs. The feasibility of achieving background concentrations will be assessed in the FS. Similar to soil, the COPCs for groundwater will be updated as new data warrant.

Other Analytes

Two VOC compounds (toluene and tetrachloroethene (PCE)) were detected in groundwater at Demo 1. Toluene was detected once in 1999 at MW-34M3 (0.2J ug/L), and twice in 1998 at MW-19S (0.4J ug/L) and MW-19D (2 ug/L). The 'J' flag indicates the concentration is an estimate based upon known data (e.g., when the mass spectral and retention time data indicated the presence of a compound that meets the volatile and semivolatile identification criteria, and the result is less than the required quantitation limit but greater than zero). These toluene concentration levels are well below the MCL of 1,000 ug/L. In 1999, PCE was detected at MW-19S in February (0.3J ug/L) and September (1 ug/L), both times below the MCL of 5 ug/L.

Antimony was detected at estimated concentrations ranging from 3.8J ug/L to 13.8J ug/L in groundwater collected from seven wells at three cluster locations: MW-34, MW-35 and MW-36. The MCL for antimony is 6 ug/L. Most of the antimony detected in these wells was slightly above the MCL with the exception of the duplicate sample for MW-35M3. As presented in the draft Technical Memorandum 99-5 (Ogden, 1999a) no statistical difference between site groundwater and background was established for antimony.

Chloramben was the only herbicide detected in the Demo 1 well network in 1999 (MW-19S at an estimated concentration of 0.14 ug/L). This one detection is significantly less than the HA for chloramben of 100 ug/L, nor was chloramben detected at MW-19S in the previous two rounds. No herbicides were detected in groundwater samples collected from well clusters MW-34, MW-35, and MW-36.

No pesticides have been detected in any of the Demo 1 monitoring wells, or periphery monitoring wells during any sampling event.

None of the VOCs, metals, or pesticides/herbicides have been identified as COPCs.

2.1.5 Ongoing and Planned Investigations

In accordance with the Final Demo 1 Response Plan, 14 additional surface soil grids were proposed and sampled in December 1999 (Ogden, 1999b). These grids extend radially out from Demo 1 area and are intended to assess the extent to which explosive contaminants may have been distributed beyond the kettle hole. The Guard will also conduct a reconnaissance of 100 percent of the ground surface within the perimeter road and 50 feet outside of it, to check for evidence of C-4 or other bulk explosives. There are historical reports of bulk explosives scattered in this area as a result of demolition training. If any bulk explosives are located in this area, they will be marked and removed to a safe holding area in accordance with UXO management procedures. Soil samples will be collected at the former location of the bulk explosives at depths of 0-3, 3-6, and 6-12 inches. Deeper sampling at these locations will be discussed with the regulatory agencies based on the results of the proposed samples. A limited reconnaissance on June 15, 1999 found evidence of C-4 along the base of the kettle hole. Results from sampling at the grids and at the bulk explosive locations will be provided in a future soil and groundwater report.

Five monitoring wells (MW-74, 75, 76, 77, and 78) were recently installed as part of the Response Plan for Demo 1 (Ogden, 1999b), to determine the vertical and lateral extent of the plume. These wells are located approximately 1200 ft downgradient of MW-19. A sixth well MW-79 was installed to evaluate groundwater conditions upgradient of Demo 1. The monitoring well results for the recently installed wells (MW-74 through MW-79) will also be discussed in a draft soil and groundwater report scheduled for June 2000.

There are currently no additional planned groundwater investigations at Demo 1, nor have any RRAs have been identified for Demo 1 in AO#3.

A munitions survey of Demo 1 is in progress and includes a geophysical survey to identify potential munitions within the perimeter road.

2.2 Central Impact Area

2.2.1 Description

The Impact Area, covering approximately 2,000 acres, contains targets at which artillery and mortars were fired during training activities. Numerous firing ranges, artillery and mortar positions, and training areas surround the Impact Area.

2.2.2 Physical Conditions

Within the Central Impact Area the groundwater elevation is typically between 60 and 70 feet ngvd and is found in the very coarse sand and gravel units. The lithology consists of a heterogeneous mixture of cobbles to silt with some stratified sand and gravel zones. The deeper lithology is generally consistent with the description provided for Demo 1.

2.2.3 History and Use

For over 50 years, the Impact Area has received ordnance discharged from small arms, guns, hand grenades, artillery, mortar, and ordnance demolition. The U.S. Army operated the area until about 1974, when it was turned over to the Army National Guard. A brief history of the use of this area was prepared prior to the start of field investigations, and is provided in the draft Range Use History Report (Ogden, 1997c).

2.2.4 Summary of Existing Soil and Groundwater Investigations

2.2.4.1 Soil

The Central Impact Area was investigated as part of the Phase I of the Impact Area Groundwater Study (IAGS). Although soil sampling results to date have not identified any significant soil contamination, a brief discussion of the analytical results is provided as background information. No explosives were detected in the soil samples collected from the Central Impact Area with the exception of pentaerythritol tetranitrate (PETN) which was detected in two surface soil samples. The detections of PETN were determined to be false-positives as discussed in Technical Team Memorandum 99-6 Evaluation of False-Positive Explosive Detections (Ogden, 2000d).

Inorganic compounds including metals, cyanide, ammonia-nitrogen, nitrate/nitrite-nitrogen, and phosphate-phosphorous were detected in all of the soil samples. Concentrations exceeding the Phase I proposed background levels were detected most frequently for manganese, copper, potassium, cobalt, chromium, magnesium, and calcium. Generally there was no observable pattern of detections with respect to sampling areas.

VOCs were detected in some surface soil samples collected from 1.5-2 feet bgs, and a few from subsurface samples collected at depths greater than 2 feet bgs. Acetone was the most commonly detected compound, accounting for 41 percent of the surface soil detections and 65 percent of the subsurface soil detections. Methylene chloride, TCE, and chloroform together accounted for 49 percent of the surface soil detections and 15 percent of the subsurface soil detections. The potential for occurrence of these compounds as laboratory contaminants has been discussed in the Draft Completion of Work Report (Ogden, 1998a). Generally there was no observable pattern of detections with respect to sampling areas.

SVOCs were detected in a number of surface soil samples collected from 1.5-2 feet bgs, and several samples collected at depths greater than 2 feet bgs. Bis (2-ethylhexyl) phthalate (BEHP) was the most commonly detected compound, accounting for 15 percent of the surface soil detections and 36 percent of the subsurface soil detections. The other detected SVOCs generally belong to two classes of compounds: PAHs and phthalates. The PAHs as a group accounted for 62 percent of the surface soil detections and 33 percent of the subsurface soil detections, with pyrene, fluoranthene, and chrysene accounting for the majority of these detections. The other phthalates detected aside from BEHP were diethyl phthalate (five percent each of the surface and subsurface detections) and di-n-butyl phthalate (nine percent of the surface soil detections and 12 percent of the subsurface soil detections). The potential for occurrence of BEHP as a laboratory contaminant is discussed in the Draft Completion of Work Report (Ogden, 1998a).

Pesticides and herbicides detected included 4,4’-DDE and 4,4’-DDT, MCPA, MCPP, 2,4,5-T, and dicamba. The later three were also detected in background samples. Nearly all compounds detected concentrations were low, i.e., less than 5 mg/kg.

No COPCs have been identified for soil at the Central Impact Area at this time. Identification of COPCs for soil will be continuously evaluated as part of the ongoing and planned site characterization activities described in Section 2.2.5. Additional AOCs and/or media may be added as a result of new data generated from investigations.

2.2.4.2 Groundwater

RDX has been detected in groundwater monitoring wells in the vicinity of or downgradient of the targets in the Central Impact Area at concentrations exceeding HAs in samples collected during Phase I of the Camp Edwards IAGS.

Table 1-1 presents the groundwater COPCs identified in AO#3 for the AOCs and the proposed PRGs. The feasibility of achieving background concentrations will be assessed in the FS. Similar to soil, the COPCs for groundwater will be updated as new data warrant.

RDX has been identified in wells that are located along three flow paths. Please refer to Figure 2-3 for well locations and RDX detections. Flow paths were developed by USGS to help define the nature and extent of contamination. These flow paths were plotted using the three-dimensional groundwater flow model MODFLOW, a modular two- or three-dimensional, finite-difference, groundwater flow model. It was selected to simulate groundwater flow at Camp Edwards. MODPATH, the USGS particle tracking code, was used to determine flow path lines in the glacio-fluvial aquifer at Camp Edwards. MODPATH uses the output from MODFLOW to compute path lines. Like MODFLOW, MODPATH is a public-domain flow code, is well documented, and is widely used throughout the environmental industry. Many pre-and post-MODFLOW processors are available to simplify model configuration and aid in graphing model output. For this study, the three-dimensional version of MODFLOW was used.

The USGS MODFLOW model for MMR is discretized using uniformly spaced model cells that are 660 ft on a side. The model includes 144 rows and 130 columns as well as 11 layers extending from the water table to bedrock. The upper boundary of the model is the water table and the lower boundary is the contact between unconsolidated glacial sediments and underlying basal till and bedrock, which were assigned as no-flow boundaries. Specified heads were used on the eastern side of the model domain for Mystic, Middle, and Hamblin Ponds and the Marston Mills River. The north and south model domains are assigned a combination of head-dependent flux boundaries, constant-flux boundaries, and no-flow boundaries see Masterson et al (1996) for additional detail.

Since the USGS model isolates and analyzes groundwater contamination into three well groups, the following discussion summarizes groundwater data for each group. However, this format is not intended to imply that three distinct areas of explosive contamination are present or originate from the Central Impact Area.

Well Group 1, the northernmost flow path, includes well clusters MW-2, MW-26, MW-41, MW-50 and MW-59. Due to its proximity to the Group 1 flow path at the MMR property boundary, the long range future water supply well LRWS 95-6 was included in the evaluation of distant downgradient contaminant migration. Well Group 2, the central flow path, includes well clusters MW-23, MW-42, MW-43 and MW-44. Well Group 3, the southernmost flow path, includes MW-1, MW-37, MW-38, MW-39 and MW-40.

Well Group 1

The MW-2 well cluster was installed during Phase I of the IAGS and is where explosive compounds along the Group 1 flow path were first discovered. The MW-2 well cluster consists of four wells completed at various depths within the aquifer ranging from the water table to 221 feet below water table (bwt) (which is approximately 70 ft to -151 ft ngvd). The sample results collected from wells comprising Group 1 revealed six detections of RDX and 4 detections of HMX out of 25 wells. (Note: well clusters or nests are located at the five wells identified in this group. To distinguish between shallow, medium and deep well samples the letter S, M, or D respectively, follow well identification numbers). RDX concentrations detected in the Group 1 range from non-detect to 13 ug/L, which was reported in MW-2M2. HMX concentrations detected in Group 1 range from non-detect to 0.84 ug/L, which was reported in MW-59S.

A groundwater sample was collected from well 95-6 (the original galvanized steel well at this location) in October 1997. It did not contain detectable explosive compounds. This well is screened between 64 and 74 feet bwt (-20 to -30 ft ngvd). Well 95-6B was sampled in March 1999. Results were non-detect for explosives in this screen, which is 93-103 feet bwt (-49 to -59 ngvd). Other wells at this location are screened at the water table and deeper in the aquifer. At the request of EPA, two of these wells were added to the Phase I sampling program in the fall of 1999. Well 95-6A, screened 142-152 ft bwt (-98 to -108 ngvd), was sampled November 9 and was non-detect for explosives. Well 95-6E(S), screened at the water table, was sampled November 16 and was also non-detect for explosive compounds.

Except for the absence of RDX in the groundwater profiles and well screens sampled at MW-41M2, groundwater quality data for the Group 1 wells show a strong relationship between the flow path and the distribution of RDX. From the Group 1 well data, it is inferred that groundwater contaminants have been introduced to groundwater in the vicinity of MW-26 and the MW-59 well cluster, and have migrated down-gradient along the flow path to at least the MW-50 well cluster. The extent of migration beyond MW-50M1 has not been determined. The non-detect at the Bourne 95-6B screen is located approximately 280 feet south of the modeled flow path. The absence of detects at MW-41 is likely the result of either variation in localized migration paths due to inhomogeneity in aquifer hydraulic properties in the vicinity of the well screen, or that the source was pulsed such that the contaminants at MW-50 have already passed through the MW-41 location.

It is possible that contaminants have been introduced to groundwater somewhat upgradient from MW-59. This possibility would explain the detections at MW-50 and MW-2 being slightly deeper than particle track from MW-59. If true, the source area would be expected to be relatively close to MW-59, since the screen where contaminants were sampled extends only 9 ft bwt (approximately 61 ft ngvd).

Well Group 2

Well Group 2 includes MW-23 installed in July/September 1997, and MW-42, 43 and 44, which were installed in the first quarter of 1999. The sample results collected from wells comprising Group 2 revealed four detections of RDX and no detections of HMX out of 28 wells (Note: well clusters or nests are located at the four wells identified in this group. To distinguish between shallow, medium and deep well samples the letter S, M, or D respectively, follow well identification numbers). RDX concentrations detected in the Group 2 range from non-detect to 4.7 ug/L as reported in MW-23M1. HMX was not detected at or above the laboratory detection limit.

Two additional well clusters have been installed cross-gradient to MW-23 and include MW-72S and the MW-51 well clusters. MW-72S is located 445 ft south of the Group 2 particle track and MW-51 is located 735 ft north of the Group 2 particle track. MW-72S is a water table well. Five well screens have been installed at MW-51 between the water table and 129 ft bwt. Explosives have not been detected in any of these monitoring wells, which have been sampled once.

Well Group 3

Well Group 3 includes MW-1 installed in the last quarter of 1997, and MW-37 through 40, which were installed in March and April of 1999. The sample results collected from wells comprising Group 3 revealed eleven detections of RDX and four detections of HMX out of 26 wells. (Note: well clusters or nests are located at the five wells identified in this group. To distinguish between shallow, medium and deep well samples the letter S, M, or D respectively, follow well identification numbers). RDX concentrations detected in the Group 3 range from non-detect to 4.6 ug/L as reported in MW-1M2. HMX concentrations detected in Group 3 range from non-detect to 0.7 ug/L.

The contamination present at MW-1M2 may be related to the detection at MW-40M1. The source area for the RDX detections appears to be upgradient of the MW-40 well cluster, since RDX was not detected in the MW-40S water table well.

The absence of RDX in downgradient wells and borings suggests that the RDX detected at MW-40M1 and MW-1M2 may not have migrated as far as MW-38, or may have dispersed or been diluted to below the detection limit. It does not appear to be likely that MW-38 is located off of the flow path from MW-1, considering the apparent relationship between the detections at MW-1S and MW-38M3 as presented in the Final Phase II(a) Response Plan for RDX in Groundwater (Ogden, 2000b).

2.2.5 Ongoing and Planned Investigations

Additional data are needed to define the lateral extent of contamination along the three flow paths. Dispersion along each flow path is likely, but as yet has not been measured. Efforts are underway to measure the lateral extent of groundwater contamination from the Demo 1 area, which may be useful for estimating the lateral spread of contaminants from the Impact Area flow paths. In order to address these data gaps, a Phase II(a) Response Plan for the Impact Area (Ogden, 2000b) was developed by the Guard and is currently being implemented. The plan includes the installation of 21 monitoring wells and the collection of soil and groundwater samples for analysis of explosive compounds, inorganic and other Phase I analytes. Groundwater profiling will be conducted in all the proposed soil borings at 10-foot intervals from the water table to the proposed bottom depths typically ranging from 80 to 100 feet bwt.

The Final Phase II(a) Response Plan (Ogden, 2000b) was developed based upon the groundwater results obtained during Phase II activities (Ogden, 1999f). Figure 2-3 shows the proposed well locations. This groundwater investigation is expected to largely determine the extent of RDX contamination throughout the Central Impact Area. Soil grid data was collected during Phase II(a) Activities in an effort to determine the source location. These data have only recently been validated and will be evaluated in the Phase II Completion of Work Report. It is anticipated that additional investigation will be required to determine the source and extent of groundwater contamination.

A munitions survey of the Impact Area is currently underway and includes a geophysics survey and excavation of High Use Target Areas (HUTAs).

RRAs are planned for two sites within the Central Impact Area. Ethylene dibromide (EDB) contaminated soils will be excavated from Study Area 2 and explosive contaminated soils excavated from beneath a pile of UXO near the Armored Personnel Carrier (APC) to the east of Turpentine Road in accordance with the Draft Rapid Response Action Work Plan (Ogden, 2000a).

2.3 Southeast Corner of the Ranges

The Southeast Corner of the Ranges is the least characterized of the AOCs. Draft work plans are currently being prepared to address this area of the Training Ranges. They will be submitted in April 2000.

2.3.1 Site Description

The J-1, J-2, J-3 and current L Range have come to be identified as the Southeast Corner of the Ranges. The J-3 wetland and adjacent private property located north of Snake Pond are included in this AOC. Access to this portion of the Site is gained via Tank Alley and Greenway Roads.

2.3.2 Physical Description

This largely vegetated area is close to the top of the groundwater mound of the Sagamore Lens. Groundwater flows radially from this high point. Groundwater within the Southeast Corner of the Ranges is found in the very coarse sand and gravel units. Based upon the data obtained from two borings advanced in this area, the lithology consists of a heterogeneous mixture of pebbles to silt with stratified sand and gravel zones. The presence and elevation of bedrock surfaces have not been determined during the investigations performed in this area.

2.3.3 History and Use

For over 50 years, the Training Ranges have received ordnance discharged from small arms, guns, hand grenades, artillery, mortar, and ordnance demolition. The U.S. Army operated the area until about 1974, when it was turned over to the Army National Guard. A brief history of the use of this area was prepared prior to the start of field investigations, and is provided in the draft Range Use History Report (Ogden, 1997c).

2.3.4 Summary of Existing Soil and Groundwater Investigations

2.3.4.1 Soil

Contaminants were detected in debris/soil within the former Steel Lined Pit at the J Ranges during Phase I activities and include the following:

HMX	9,300 ug/kg
2,4-DNT	200 ug/kg
di-n-butylphthalate	80 ug/kg
pentachlorophenol	37 ug/kg
aluminum	24,600 mg/kg
lead	616 mg/kg
magnesium	2,720 mg/kg
barium	1,140 mg/kg
copper	2,350 mg/kg
cadmium	33.3 mg/kg

The debris/soil within the Steel Lined Pit was removed and placed in a pile on plastic and covered with additional plastic during the original UXO clearance. The soils were subsequently placed into 55-gallon steel drums by the MAARNG on March 26, 1998. The soil is currently stored at the MW-58 drill pad, which is located adjacent to the former location of the Steel Lined Pit. The drummed soils at the Steel Lined Pit area are being managed as part of the RRAs required by AO#3. The Steel Lined Pit structure was removed on approximately October 22, 1999 and placed on the ground surface to facilitate the installation of monitoring well MW-58. The subsequent hole was covered with a polyvinyl liner and clean soil was placed on top of the liner to fill in the depression.

Additionally, two soil borings were placed adjacent to the Steel Lined Pit with soil samples collected from 3 to 4, 4 to 5, and 5 to 6 ft bgs. The data from all of the soil samples do not indicate elevated metal levels as compared to soil cleanup standards presented in Tables 1 and 2 of the Draft Work Plan RRA and Release Abatement Measure Plan (Ogden, 2000a). The data indicate that the metals in the debris in the pit have not migrated to the soil.

Soil contamination identified at the steel lined pit will be addressed by the RRA. Otherwise, no COPCs have been identified for soil at the Southeast Corner of the Ranges at this time. Identification of COPCs for soil will be continuously evaluated as part of the ongoing and planned site characterization activities discussed in Section 2.3.5. Additional AOCs and/or media may be added as a result of new data generated from investigations.

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2.3.4.2 Groundwater

Explosives have been detected in wells within the Southeast Corner of the Ranges and close to the J Ranges. RDX has been detected in groundwater monitoring wells in the vicinity of the J Ranges in excess of USEPA's HA of 2 ug/L for RDX as follows:

90WT 0013	5.2 ug/L
90MW 0022	5.4 ug/L

HMX has been detected in monitoring well MW-30S installed near the melt-pour facility on the J-3 Range at 12 ug/L.

Explosives have been detected in wells outside of the Training Ranges and Impact Area north of Snake Pond close to the J Ranges. Well 90MW0022 installed by the Air Force Center of Excellence (AFCEE) for monitoring and/or characterization of the fuel spill-12 (FS-12) hydrocarbon plume is located downgradient of the J Ranges. This well is located on the south side of the groundwater mound and groundwater flows to the south in this area. The first time 90MW0022 was sampled as part of the IAGS was on January 14, 1998, and no explosive compounds were detected. However, a later sample from January 16, 1999 indicated the presence of RDX at a concentration of 3.8 ug/L. A third sample collected on February 16, 1999 indicated RDX at a level of 5.4 ug/L. All three of these sample results have been validated. Figure 2-4 presents the detected explosive compounds in groundwater at the Southeast Corner of the Ranges.

Groundwater profiling was conducted by AFCEE in response to hydrocarbons detected in a residential well near Snake Pond. Split samples were collected by Ogden and analyzed for explosives. Samples from two of the drive point locations, DP-8 and DP-9, indicated the presence of RDX and HMX. At location DP-8, RDX was detected in the depth interval of 55 to 80 ft bgs or approximately 22 to –3 ft ngvd. The highest concentration of RDX was observed in the sample from a depth of 80 to 85 ft bgs (-3 to –8 ft ngvd) and the highest HMX level was in a sample from 55 to 60 ft bgs (22 to 7 ft ngvd). At location DP-9, RDX was detected at a concentration of 4.6 ug/L in the 70 to 75 ft bgs sample interval. Samples were also collected from DP-2 and DP-4 and no explosives were detected in any of the samples. DP-2 and DP-4 are located to the west of the projected particle tracks from 90MW0022 and DP-8/9.

Thirty-two existing IRP wells located in the FS-12 area have also been previously sampled as part of the IAGS for explosives. In addition, 15 residential wells, screen elevations unknown, located downgradient (southeast) of 90MW0022 have been sampled and analyzed for explosives. Explosive compounds have not been detected in any of the residential wells.

Table 1-1 presents the groundwater COPCs identified in AO#3 for the AOCs and the proposed PRGs. The feasibility of achieving background concentrations will be assessed in the FS. Similar to soil, the COPCs for groundwater will be updated as new data warrant.

2.3.5 Ongoing and Planned Investigations

Additional investigations at the Southeast Corner of the Ranges are pending. The Draft Response Plan for RDX Detections at DP-8, DP-9 and 90MW0022 (Ogden, 2000c) proposes groundwater sampling at specified downgradient well locations. The purpose of the sampling is to conduct an initial assessment of groundwater quality and groundwater flow downgradient of the J Ranges.

The L Range, located in the southeast corner of the ranges, is documented as a high use target area for explosive grenades. The Draft Phase II(b) Workplan (Ogden, 1999c) proposes additional investigations at several training and military ranges including the current L Range. However, based upon the proximity of the L Range to the J Ranges, the proposed investigation at the L Range will be incorporated into the J-1/J-3 Ranges Work Plan.

The draft J-2 Range Workplan and the draft J-1, J-3 and L Ranges Work Plan are in the planning stage. Both plans will outline the objectives for initial field investigations at each location. Submittal dates for the Draft J-2 Range Workplan and Draft J-1, J-3 and L Ranges Work Plan are 7 and 21 April 2000, respectively.

A RRA is proposed for the J-3 Wetland, which is located approximately 500 feet southeast of 90MW0022. The limits of the J-3 Wetland have previously been established. Excavated soils associated with both the J-3 Wetland and the Steel Lined Pit will be treated by soil washing and biotreatment as documented in the Draft Rapid Response Action Workplan (Ogden, 2000a).

2.4 Unexploded Ordnance (UXO)

Camp Edwards has been used for weapons training throughout its history beginning in the late 1930s and continuing into the late 1990s. Historical records and visual evidence have revealed that during this 60-year period, training exercises made use of a variety of weaponry ranging from small caliber rifles and machine guns to 105 mm and 155 mm artillery pieces.

Evidence of rounds fired from these weapons is obvious in surface and near-surface soils on ranges throughout the Impact Area and in certain portions of the surrounding training areas (Figure 1-1). Occasional misfires of live rounds resulting in detonation failure have resulted in intact UXO and ordnance remnants (fragmentation) including artillery projectiles, rockets, mortars, grenades, and mines in the vicinity of many past and present range targets. Alleged stockpiling and past ordnance disposal practices within the Impact Area have created other possible concentrations of UXO.

2.4.1 UXO Description

The propellants and high explosive fillers of military ordnance comprise mixtures of explosive and inert compounds that, in UXO and as residue on fragmentation, present a potential source of contaminants to the environment. Intact and spent pyrotechnic devices used in combat training such as smoke grenades and artillery simulators also present a release potential.

Releases from intact UXO and pyrotechnic devices can occur through leakage from threaded joints, corrosion pits, and as free product in situations where low-order detonations fail to consume the entire filler contents releasing it directly to the ground surface. Though the filler contents of training rounds are inert, the fuse or initiator components of these types of ordnance contain explosive compounds as well.

Typical chemical constituents of fillers, fuses, propellants, and pyrotechnic devices are discussed below (excerpt from Draft Chemical Composition of Munitions Report, Ogden, 1997d).

2.4.1.1 Explosives

Explosive materials have the potential to chemically change from the solid state to large volumes of hot gases very quickly. High Explosives (HE) are materials that undergo change at a rate faster than the speed of sound. Examples of such materials are TNT, Amatol, and mercury fulminate. Low explosives (LE), such as black powder, smokeless powder, and rocket propellant, are those materials that undergo the change at speeds slower than the speed of sound.

The variation in the properties of explosives is put to use in armaments (explosive rounds) by an arrangement known as the "Explosive Train" - an arrangement of elements according to decreasing sensitivity and increasing potency. The primary explosive usually constitutes the initiator (heat, spark, impactor, friction) of the train. The second element, the booster, usually contains a less sensitive material that is a high explosive. The third and final component, the bursting charge, consists of a secondary explosive. Each of these elements introduces a unique combination of chemical constituents to the armament.

2.4.1.2 Propellants

Propellants are divided into the following categories based on composition:

- Single-Based Compositions - contain nitrocellulose as the chief ingredient, and may contain inorganic nitrates, nitro-compounds, and non-explosive compounds, such as metals, metallic salts, carbohydrates, and dyes.
- Double-Based Composition - generally apply to compositions containing both nitrocellulose and nitroglycerin. Like the single-based propellants, double-based propellants usually contain additives.

- Triple-Based Composition - apply to propellants containing three explosive ingredients with nitroguanidine as the primary ingredient, in addition to components of this class of propellants.
- Mixed Nitrate Esters or Composite Propellants - a class of propellants produced by mixing and matching the other three classes or propellants; all usually have the same components except for nitroguanidine. This class of propellants was developed primarily as a replacement for the triple-based propellants.

Single-based propellants are used in cannons, small arms, and grenades; double-based compositions are used in cannons, small arms, mortars, rockets and jet propulsion units; and triple-based propellants are used exclusively in cannon units. Composite propellants are used primarily in rocket assemblies and propulsion units. The choice of propellant is based on ballistic and physical requirements, and a given propellant composition could be suitable for several applications.

2.4.1.3 Pyrotechnics

Pyrotechnic compositions are divided into the following categories based on use:

- Flare and Signals - burn to produce light for illumination. Signals produce colored flames that are used as semaphores.
- Colored and White Smoke for signaling.
- Tracers and Fumers - used as small smoke producing charges placed in projectiles; and used to track the flight of the projectile. Fumers are used to produce smoke at the proper time to fill vacuums created behind the projectile so as to reduce the drag on the projectile.
- Incendiaries - produce large amounts of heat for the purpose of causing fires.
- Delays and Fuses - designed to burn for a predetermined time, and used to provide an interval between ignition and detonation of an explosive. A delay is an explosive igniter that consists of an initiator, a delay column, and an output charge and a fuse is a length of cord made of flammable material attached to a device to provide the same effect.
- Photoflash Composition - a loose mixture of oxidizers and metallic fuels that, when ignited, burns with explosive violence in a very short time. Photoflashers are used for military aerial photography.
- Igniters and Initiators - used to ignite propellants and initiate detonation of explosive charges.

Table 2-1 provides a detailed list of typical explosives, propellants, and pyrotechnic compounds, as well as their degradation products, historically used by the military at Camp Edwards.

2.4.2 Physical Conditions

The condition of UXO observed in surface and near surface soils to date at Camp Edwards range from recently fired rounds that exhibit little to no evidence of

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environmental degradation, to heavily corroded ordnance exhibiting degradation beyond the point at which a positive identification can be made. A more detailed evaluation of the potential and extent of corrosion is planned as part of the characterization activities.

Historically, most UXO at Camp Edwards has been discovered at the surface through visual observations made by range personnel. More recently, in an effort to reduce the physical hazards of working in potential UXO areas, visual observations during the IAGS have been supplemented with remote sensing surveys using metal detectors and magnetometers to provide safer work environments within the Impact Area. These clearance surveys have shown that a small percentage of UXO within the Impact Area exists below ground, obscured from view, in near surface soils.

2.4.3 History and Use

The following section presents a general history of each gun position, mortar position, and range where large caliber ordnance was historically fired. Most of the training ranges used to fire large caliber weapons are located around the perimeter of the Impact Area (Figure 1-1) targeting on sites within the Impact Area. Some of the earlier ranges (Old A, Old B, Old C, and Old D) were located beyond the Impact Area perimeter in relatively isolated spots south and west of the Impact Area. Gun positions and mortar positions have been historically and recently located outside the southern, western and northern regions of the Impact Area and targeted sites within the Impact Area. Many of the known targets within the Impact Area are shown in Figure 1-1.

Table 2-2 provides a summary of former and current gun and mortar positions and Table 2-3 lists present and past training ranges at Camp Edwards along with their respective use histories including location, weaponry used, ordnance fired, and target areas are also provided in the table.

2.4.4 Summary of Existing Information

Existing data on UXO discoveries at Camp Edwards have been obtained through UXO clearance operations performed prior to field investigation activities under the IAGS. During these site clearance operations, numerous UXO have been located and identified. Table 2-4 provides a summary of UXO discoveries during Phase I and to date during Phase II surface clearance activities. Table 2-5 provides a summary of UXO discoveries during Phase I and Phase II intrusive clearance activities.

2.4.5 Ongoing UXO Characterization

Efforts are currently underway to characterize the nature and extent of UXO and its potential impacts on soil in the vicinity of the HUTAs. The objectives of this investigation are to: 1) characterize the distribution and mass of UXO existing within the HUTA, 2) determine the potential release mechanisms and possible release scenarios posed by UXO in the environment, and 3) evaluate the migration characteristics of UXO-generated contaminants.

Specific COPCs have not been identified for UXO at this time. Investigations and evaluations of UXO and its potential impact to groundwater are currently underway. The activities planned are described below.

2.4.5.1 Distribution of UXO

Understanding the distribution of UXO, the numbers, types, and locations of UXO within the HUTA is essential in assessing the magnitude of the potential impacts these ordnance constituents pose to groundwater, and for providing the basis for properly evaluating remedial alternatives. Several document archive searches and interview sessions were conducted early in the IAGS that provided a general understanding of the nature of training and associated activities performed in the HUTA. The results are being used to design the HUTA UXO investigation.

Groundwater monitoring wells MW-1 and MW-2 were selected as representative sites within the HUTA where UXO discoveries are anticipated. The investigation will begin with surface reconnaissance to identify surface UXO and related material. A geophysical survey will be conducted to remotely detect buried UXO and related material. UXO-type anomalies detected in the geophysical surveys will be excavated for identification, characterization, and possible removal depending on the degree of danger associated with moving individual items. Planning efforts for this investigation are currently underway by the Guard utilizing Tetra Tech to perform the site characterization.

2.4.5.2 Release Potential

To accurately assess the release potential for explosive compounds in UXO, it will be critical to understand the mechanisms by which these compounds are liberated from UXO into the environment. This assessment will consider information gathered from continued literature searches on the nature of metals corrosion in the environment and the associated manner in which contaminants could theoretically be released from UXO.

Representative soils will be collected from beneath UXO removed during the HUTA UXO location surveys. Samples will be tested for constituent explosive compounds to gather information on actual contaminant releases from individual rounds. These results will be compared to the literature findings to better characterize the actual release processes and understand UXO contaminant behavior at Camp Edwards.

Deeper soil samples will be obtained from areas of known UXO-related contaminant releases for laboratory testing. The results of the data collection activities will be presented in a UXO site characterization report.

2.4.5.3 Contaminant Migration

In order to fully understand how released compounds pose threats to groundwater, a reasonable understanding of specific contaminant behaviors in the environment is necessary. An assessment of the fate and transport characteristics of specific, selected explosive, propellant and pyrotechnic compounds originating from Impact Area UXO will be conducted as part of the fate and transport modeling currently planned for Camp Edwards (Ogden, 1999d).

Additional information will be gathered from existing literature on the nature of explosive compound behavior in soil supplementing information currently available in the Draft Fate and Transport of Munitions Report (Ogden, 1997e). The results of HUTA soil testing for deeper soils will be considered with this information on contaminant fate and transport from the literature search and modeling results to establish general migration characteristics within the Camp Edwards unsaturated zone. Data on groundwater quality obtained during earlier phases of the IAGS downgradient of the HUTA will be included in the contaminant migration assessment.

2.4.5.4 Preliminary Risk Evaluation

Based on findings from the site characterization activities described above, a preliminary evaluation of the risk to groundwater will be performed for known Camp Edwards UXO. The evaluation will consider UXO distribution (as determined from archive reports and the HUTA investigation), release mechanisms, and environmental fate and transport for contaminants. Ordnance types and their associated contaminants posing unacceptable risks to groundwater will be identified. UXO varieties known or suspected of being present at Camp Edwards can then be ranked based on their likelihood to impact groundwater forming the basis for establishing remedial action objectives for UXO.

The results will provide a benchmark from which a preliminary evaluation of potential groundwater impacts can be determined for the HUTA. From this preliminary evaluation, potential UXO of concern can be selected, and the screening of preliminary remedial action alternatives can begin.

2.5 Chemical Spill (CS)-19

Groundwater and soil contamination at CS-19 are being addressed by the Air Force under the IRP. An FS must be performed on this area only if the USEPA determines that remediation proposed under the IRP program is not adequate. Therefore, summary information is provided below, but remedial measures and data requirements for this area are not included in the FSWP.

The CS-19 site is a small area in the west-central region of the Impact Area that was used for the disposal of munitions, among other things. RDX has been detected in groundwater monitoring wells in the vicinity or downgradient of CS-19, in excess of USEPA's HA of 2 ppb for RDX. Contaminants have also been detected in surface and subsurface soils at CS-19. The soil and groundwater contamination related to CS-19 lie within the zone of contribution for Long Range Water Supply 8, a potential water supply well site being investigated as a future public drinking water well.

3.0 ADDITIONAL CHARACTERIZATION REQUIREMENTS

Prior to finalizing the Development and Initial Screening of Alternatives Report for each of the AOCs, it is critical to have identified the nature and extent of the contamination and developed PRGs for affected media. The Guard proposes to overlap the execution schedules for FS activities and characterization to the extent feasible to expedite the selection of appropriate remedial alternatives.

The objective of this section is to summarize the currently identified additional characterization requirements for each AOC. The requirements that encompass all the AOCs are discussed in Section 3.1 Site-Wide Characterization Requirements. AOC-specific requirements are discussed in the subsequent sections.

Each AOC is at a different stage of characterization based on existing, ongoing and planned investigations. Therefore, each AOC will have a unique timeline for completion of the necessary characterization activities and subsequent work components. Each AOC may be subdivided into Operable Units (OUs), as appropriate based on the characterization data, to expedite the selection of Remedial Alternatives for individual OUs or AOCs.

3.1 Site-Wide Characterization Requirements

3.1.1 Fate and Transport Modeling

Fate and transport modeling is currently being planned for Camp Edwards (Ogden, 1999d). The modeling is being conducted as part of the site characterization phase under the IAGS Program. The objectives of the unsaturated and saturated zone modeling for Camp Edwards include the following: 1) predict future directional path, rate of movement, and concentrations of contaminants emanating from Camp Edwards, 2) determine acceptable soil PRGs for contaminants deemed protective of groundwater quality, 3) identify sources of groundwater contamination, and 4) provide a basis for making risk management decisions. The development of PRGs will rely on the use of an unsaturated zone model to simulate the movement of contaminants at the ground surface to the water table. Then, a saturated zone model will be used to predict contaminant concentrations at the potential receptor locations. The contaminant concentrations predicted by the saturated zone model will be used to determine what contaminant levels in soils would likely result in an unacceptable impact on groundwater.

3.1.2 Groundwater Sampling

Additional rounds of groundwater data are required to characterize the existing groundwater contamination at each of the AOCs. Collection of the groundwater data is discussed in more detail in Section 7.0 Long Term Monitoring Plan.

3.2 Demo 1

Demo 1 is currently the best-characterized AOC. Based on the existing data and ongoing and planned investigations, Demo 1 will be subdivided into two OUs. A Groundwater OU and a Soil OU will be established to allow the soil and groundwater components to be evaluated on separate timelines.

3.2.1 Groundwater Operable Unit

The existing monitoring well network associated with Demo 1 (Figure 2-2) adequately characterizes the nature and extent of current groundwater contamination at the site. The current downgradient extent of the contamination is defined by MW-32, MW-33 and MW-35 that have not contained any COPCs. The well fence that includes MW-74 through MW-78 will define the width of the groundwater contamination. This well fence has been installed and the results will be presented in a draft soil and groundwater report to be submitted on 8 June 2000. Additional rounds of groundwater sampling at existing monitoring wells will be conducted in accordance with the Interim Long Term Groundwater Monitoring Plan (Ogden, 2000e) and the Final Response Plan for Demo Area 1 (Ogden, 1999b).

No additional groundwater monitoring wells are proposed for the purpose of initiating preparation of the Development and Initial Screening of Alternative Report. An additional well to the south of MW-34 may be required in the future to define the lateral extent of downgradient groundwater contamination. This decision will be made based on the analytical results of groundwater sampling of MW-74 through MW-78 and a detailed evaluation of local groundwater flow contours. If necessary, this additional work will be proposed in a work plan and will be conducted as part of the ongoing IAGS Program. The data, if collected, will be factored into the detailed evaluation of remedial alternatives for this OU.

3.2.2 Soil Operable Unit

Additional soil investigations are required at Demo 1 to adequately characterize potential source areas. The Final IAGS Technical Team Memorandum 99-2, Deep Soil Sampling of Demolition Area 1 (Ogden, 2000g) recommends additional soil sample locations east of the original sampling locations in Demo 1. A network of nine (9) additional soil borings is proposed in the eastern portion of the depression, surrounding and upgradient of MW-19. A Field Sampling Plan (FSP) is provided for these activities in Section 6.2.1 Field Sampling Plan.

Upon completion of these additional borings it is anticipated that the nature and extent of the Demo 1 Soil OU will be adequately characterized.

3.3 Central Impact Area

Additional investigations are currently being conducted according to the Final Phase II(a) Response Plan for Impact Area RDX Detection in Groundwater (Ogden, 2000b). This work includes the installation and sampling of several proposed monitoring wells (Figure 2-3). The wells are aligned in two fences to define the width of the groundwater contamination at two downgradient locations of the three well groups associated with the USGS modeled particle tracks.

Additional monitoring wells will likely be required to determine the downgradient extent of the groundwater contamination. The need for this additional work will be determined based upon the results of ongoing investigations. If necessary, this additional work will be proposed in a response plan and will be conducted as part of the ongoing IAGS Program. The data, if collected, will be factored into the detailed evaluation of remedial alternatives for this OU.

3.4 Southeast Corner of the Ranges

As discussed in Section 2.0, work plans for the J-2 Range and J-1, J-3 and L Ranges are currently being prepared to investigate potential contamination associated with the past use of the ranges. The need for additional investigations to characterize the Southeast Corner of Ranges, beyond those currently being planned, can not be determined at this time. As results are reported for the ongoing investigations, the need for supplemental investigations to characterize the nature and extent of contamination will be assessed and discussed with the USEPA and Massachusetts Department of Environmental Protection (MADEP).

3.5 UXO

Other areas outside of the HUTAs have historically been used for training activities involving explosive and pyrotechnic ordnance. Should the results of the HUTA 1 characterization efforts indicate that UXO pose a threat to groundwater, other training areas of potential concern will be considered for UXO investigation based on historical activities. Lessons learned during the HUTA 1 investigation on locating UXO, determining surface and subsurface ordnance distribution, contaminant releases mechanisms, and migration potential will be used to focus the investigation of other areas at Camp Edwards.

3.6 Preliminary Conceptual Site Model

A conceptual site model typically includes known and suspected sources of contamination, types of contaminants and affected media, know and potential routes of migration, and know or potential human and environmental receptors. Figure 3-1 presents a simplified site conceptual model encompassing the known features of the Training Ranges and Impact Area and showing the potential sources and transport mechanisms for contaminants.

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The most likely source of contamination at the Training Ranges and Impact Area is explosives. The primary release mechanisms appear to be demolition activities, release of explosives from UXO, and exploded ordnance residuals. These activities potentially release explosive compounds to the near surface soil. From the soil it appears that the explosive compounds are transported through the unsaturated zone via infiltration and percolation to the saturated zone. The migration pathway to be considered under the SDWA is groundwater flow of dissolved contaminants and potential ingestion of contaminated groundwater. The site conceptual model will be continuously updated as data is generated from site characterization activities at the Training Ranges and Impact Area. The fate and transport modeling (Ogden, 1999d) and UXO characterization activities will provide valuable information to update the site conceptual model.

4.0 FEASIBILITY STUDY PROCESS

The objective of this section is to describe the components and process required to complete the FS process for the AOCs. The FS will develop, screen and evaluate remedial alternatives that will be protective of human health and the environment. The FS for the AOCs identified in AO#3 will be conducted in general conformance to the USEPA *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (USEPA, 1988). The primary objectives of the FS are provided in Section 1.2.

4.1 Feasibility Study Process Overview

The FS evaluates remedial alternatives for treatment, disposal, and/or containment of COPCs for the AOCs. After identifying and characterizing the AOCs, remedial action objectives (RAOs) are developed. RAOs are site-specific, quantitative goals defining the extent of cleanup required to achieve response objectives. Appropriate remedial technologies are identified for each AOC that ensure the protection of human health and the environment based on the remedial action objectives. Each technology is screened, or cursorily evaluated, to eliminate the options that are obviously infeasible. Technologies that remain after the initial screening either become or are combined to be remedial action alternatives. The remedial action alternatives are evaluated in detail to determine their advantages and disadvantages.

4.2 Development of Remedial Action Objectives

One or more RAOs are developed for each AOC. They specify the contaminants, media of interest, exposure pathways, and preliminary remediation goals to be used in developing remediation technologies. They are also used as part of the criteria for evaluation of remediation technologies. Preliminary RAOs have been developed in Section 5.2 and will be updated in the Development and Initial Screening of Alternatives Report.

4.3 Development and Initial Screening of Alternatives

For each AOC, combinations of technologies are developed to address remediation requirements. There are several steps to this process:

1. Develop general response actions that will satisfy remedial action objectives for each medium of interest in each AOC. These include broad categories such as treatment, containment, excavation, extraction, disposal, or some combination of these. Response actions are generally medium-specific.

2. Define the volumes or areas of the AOCs that apply to each given response action.

3. Identify remediation technologies, including innovative ones, and determine to what extent each technology may satisfy the applicable remediation goals and objectives.

4. Screen the technologies to eliminate those that cannot be implemented technically at the AOCs. For each technology, different process options for implementing the technology are identified and evaluated. One process that best meets the criteria for technical implementability may be selected for each technology for the purposes of the FS.

5. Evaluate each technology in terms of its effectiveness, implementability, and relative cost. The technology is then eliminated or retained for further consideration.

6. Combine the technologies into alternatives that represent a range of treatment, containment, and/or disposal options for the remedial action goals for each AOC. The alternatives developed for each AOC will include, per AO#3:

    a. An alternative that reduces the COPC concentrations to background conditions to the extent technically practicable.

    b. An alternative that reduces the contaminant concentrations to levels that meet or exceed all MCLs, HAs, DWELS, and an unacceptable excess lifetime cancer risk.

    c. A no action alternative to serve as a baseline for alternative comparisons.

    d. For source control actions, a range of alternatives in which treatment that reduces the toxicity, mobility, or volume of the contaminants is a principal element. As appropriate, this range will include an alternative that removes contaminants to the maximum extent feasible, eliminating or minimizing, to the degree possible, the need for long-term management. This range will include other alternatives that will treat the principal threats posed by the AOC but vary in the degree of treatment employed.

    e. For groundwater remedial actions, remedial alternatives that attain PRGs within different restoration time periods will be developed, including innovative technologies. The alternatives will utilize one or more different technologies that offer the potential for comparable or superior performance or implementability; fewer or lesser adverse impacts; or lower costs for similar levels of performance.

    f. For UXO remedial alternatives, technologies that remove UXO from environment while minimizing any release of contaminants to soil and groundwater will be developed.

7. Identify and evaluate appropriate handling, treatment and final disposal of all treatment residuals.

8. Conduct an initial screening of alternatives that considers the short and long term aspects of the following three criteria:

    a. Effectiveness. This criterion focuses on the degree that an alternative restores and protects the sole source aquifer underlying the Training Ranges and Impact Area as a future water supply; reduces toxicity, mobility, or volume through treatment; minimizes residual risks and affords long-term protection; complies with Regulations, and minimizes short-term impacts. It also focuses on how quickly the alternative achieves the PRGs;

    b. Implementability. This criterion focuses on the technical feasibility and availability of the technologies that each alternative would employ and the administrative feasibility of implementing the alternative;

    c. Cost. The costs of construction and any long-term costs to operate and maintain the alternatives will be evaluated.

This information is documented in the Development and Initial Screening of Alternatives Report. This report will contain tables that screen the alternatives and provide an evaluation and analysis of the factors described above. Justification will be provided for deleting, refining or adding alternatives. Site characterization information will be summarized in the report and graphical presentations of the extent of contamination will be utilized to the extent practicable.

4.4 Post-Screening Investigations

Some alternatives, particularly those involving innovative technologies, may require additional field and/or laboratory investigations to obtain data needed to complete a detailed analysis. Potential post-screening investigations include supplemental literature and vendor searches, bench and/or pilot scale treatability studies, and collection of field data required to characterize an AOC.

The need for post-screening investigations will be determined based on the retained alternatives described in the Development and Initial Screening of Alternatives Report and an evaluation of the data needs to complete the detailed analysis. If post-screening investigations are required, a Post-Screening Investigations Work Plan will be developed that delineates the objectives, procedures and methods of the investigations. The results of any post-screening investigations will be reported in the FS or a separate Post-Screening Investigation Report.

4.5 Detailed Analysis of Alternatives

The detailed analysis of alternatives will consist of the following components:

- further definition of each alternative with respect to the volumes or areas of contaminated media to be addressed, the technologies to be used, and any performance requirements associated with those technologies;

- a process scheme for each alternative that describes how each process stream, waste stream, emission residual, or treatment product shall be handled, treated and/or disposed;

- an assessment and a summary profile of each alternative against the nine evaluation criteria described below

- a comparative analysis among the alternatives to assess the relative performance of each alternative with respect to each evaluation criterion.

The remedial alternatives retained after the initial screening are then analyzed in detail with respect to evaluation criteria. These criteria include:

1. *Overall protection of human health and the environment* defined for each AOC within this project through the remediation goals and objectives.

2. *Compliance with the applicable or relevant and appropriate requirements (ARARs)* of state and federal environmental laws, including chemical-specific, location-specific, and action-specific ARARs.

3. *Long-term effectiveness and permanence*, considering the magnitude of risks remaining after completion of the RA; the type, degree, and duration of post-remediation care required; the potential for exposure of human and environmental receptors to regulated substances remaining at the site; the long-term reliability of any engineering and voluntary institutional controls; the potential need for repair, maintenance, or replacement of components of the remedy; and the time required to achieve cleanup standards.

4. *Reduction of toxicity, mobility, and volume through treatment*, including the amount of regulated substances that will be removed, contained, treated, or destroyed; the degree of expected reduction; the degree to which the treatment is irreversible; and the type, quantity, toxicity, and mobility of regulated substances remaining after implementation of the remedy.

5. *Short-term effectiveness*, including an evaluation of the short-term risks that may be posed to the community, workers or the environment during implementation of the remedy, the amount of time until remedial response objectives are achieved, and the effectiveness and reliability of protective measures to address short-term risks.

6. *Implementability*, considering commercially available remedial measures that are the best available demonstrated technology, degree of difficulty associated with constructing the remedy, expected operational reliability, ability to monitor effectiveness of the technology, available capacity and location of needed treatment, availability of storage and disposal services for wastes, time to initiate remedial actions, coordination between various groups required to implement the technology, and approvals necessary to implement the remedial efforts.

7. *Cost*, including the direct and indirect capital costs, operation and maintenance costs, the net present value of those costs, and the total costs and effectiveness of the system. A cost-sensitivity analysis may also be evaluated, including such factors as the effective life of the RA, operation and maintenance costs, volume of material to be treated, system design parameters, and the discount rate.

8. *State acceptance,* including an evaluation of technical and administrative issues and concerns the state may have with each alternative. This criterion is normally addressed once comments on the FS have been received.

9. *Community acceptance*, including an evaluation of issues and concerns the public may have with each alternative. This criterion is evaluated after the public comment period.

The results of this evaluation will be documented in the Draft FS Report. The report will include graphical presentations that allow for comparisons of multiple alternatives at various costs, completion times and clean-up levels.

4.5 Remedial Alternative Selection Process

After USEPA approval of a Draft FS for an AOC, a Remedy Selection Plan will be developed. The Remedy Selection Plan will summarize the characterization data and detailed analysis of alternatives and identify the proposed Remedial Alternative that provides the best balance of the evaluation criteria for the AOC or OU. The selection of the proposed remedy will be reached through a collaborative process among the Guard, USEPA, MADEP and the public that takes place throughout the site characterization and FS process via review of documents, public and technical meetings, and other means of communication such as fact sheets and poster board sessions.

AO#3 does not require preparation of a Remedy Selection Plan. However, it is included in the remediation process to facilitate public participation in the remedy selection process. After approval of the Remedy Selection Plan by the USEPA and MADEP, the plan will be submitted for public comment. Upon incorporation of public comments, the selected Remedial Alternative will be described in a final Decision Document that details the specific components and performance objectives of the remedy.

5.0 POTENTIAL REMEDIAL TECHNOLOGIES

This section identifies preliminary RAOs and a preliminary list of potential remedial technologies that may be applicable to soil and groundwater contamination currently identified at the Training Range and Impact Area. Preliminary technologies for remediation of UXO are also identified. The initial list of technologies may change as new site characterization data is generated. This section also identifies data that would likely be required to complete a detailed evaluation of the technologies. The technologies will be screened and assembled into alternatives as part of the Development and Initial Screening of Alternatives Report.

5.1 Preliminary Remedial Response Objectives

AO#3 identified several preliminary objectives for the development and screening of alternatives. Remedial alternatives will be developed that:

1. Provide an appropriate level of protection to the aquifer underlying the AOCs.
2. Protect human health and the environment by recycling waste or by, eliminating, reducing, and/or controlling risks to human health and the environment posed through each pathway at the Area of Concern.
3. Consider the long-term uncertainties associated with land disposal.
4. Consider the goals, objectives, and requirements of the Solid Waste Disposal Act.
5. Consider the persistence, toxicity, mobility, and propensity to bioaccumulate of the contaminants.
6. Consider the short and long term potential for human exposure.
7. Consider the potential threat to human health and the environment if the remedial alternative proposed was to fail.
8. Consider the threat to human health and the environment associated with the excavation, transportation, and disposal or containment of contaminated substances and/or media.

5.2 Remedial Action Objectives

Preliminary RAOs for soil, groundwater and UXO have been developed for the Training Ranges and Impact Area. RAOs specify the contaminants of concern, media of interest, exposure pathways, and preliminary remediation goals to be used in developing remediation technologies. The RAOs for soil and groundwater are generic for all AOCs at this time. AOC specific and more detailed RAOs will be developed as additional site characterization data is collected and site-specific preliminary remediation goals are calculated.

The preliminary RAOs for soil, groundwater and UXO are presented below.

Soil	Prevent migration of explosive compounds from soils that would result in groundwater contamination in excess of background levels (to the extent technically practicable), MCLs, HAs, DWELs, and/or an unacceptable excess lifetime cancer risk.
Groundwater	Prevent ingestion of water containing explosive compounds in excess of background levels (to the extent technically practicable), MCLs, HAs, DWELs, and/or an unacceptable excess lifetime cancer risk.
UXO	Prevent migration of explosive compounds from UXO that would result in groundwater contamination in excess of background levels (to the extent technically practicable), MCLs, HAs, DWELs, and/or an unacceptable excess lifetime cancer risk.

5.3 Identification of Potential Remedial Technologies

The Final Evaluation of Remediation Technologies for Demolition Area 1 (Ogden, 2000h) evaluated remedial technologies to address explosive contaminants present in soil and groundwater at Camp Edwards. This report described a preliminary evaluation of potentially applicable remediation technologies based on COPCs identified at Demo 1. The list of COPCs for each AOC will be updated as the characterization phase is completed for each AOC. Since explosives are the primary contaminants detected at all AOCs the soil and groundwater remedial technologies identified below represent all AOCs based on the current data.

The focus of this evaluation is on preliminary identification and screening of technologies. It should be recognized that many of the potential technologies could be combined to reduce cost or increase overall effectiveness. Assembling technologies into alternatives will be completed as part of the Development and Initial Screening of Alternative Report for each AOC or OU.

The approach used to identify applicable technologies for explosive remediation was to first consider all technologies available, including innovative technologies. The next step was then to determine which technologies could remediate explosive compounds. During this stage a large number of technology categories were determined not suitable for explosives remediation, such as thermal, vapor, surfactant, and co-solvent methods for groundwater, and vapor technologies for soil. Specific examples of the vapor phase technologies not suitable for explosives remediation include; Bioslurping, Dynamic Underground Stripping (DUS), and UVB systems for groundwater and soil vapor extraction (SVE), Six-Phase Heating, and Steam Stripping for soil.

Potential technologies for remediation of soil and groundwater are identified Tables 5-1 and 5-2 respectively. Each of the technologies for soil (Section 5.4) and groundwater (Section 5.5) are discussed in the following sections. The Final Evaluation of Remediation Technologies for Demolition Area 1 (Ogden, 2000h) also evaluated each of the technologies against the following seven criteria; 1) overall protection of human health and the environment, 2) compliance with applicable or relevant and appropriate requirements (ARARs) 3) long-term effectiveness and performance, 4) reduction of toxicity, mobility, or volume through treatment, 5) short-term effectiveness, 6) implementability, and 7) cost. This type of detailed evaluation will be revisited in the FS once the technologies are assembled into alternatives in the Development and Initial Screening of Alternatives Report for each AOC.

5.4 Potential Soil Remedial Technologies

As discussed in Section 2, soil remediation is currently being considered only at Demo 1 under this FSWP. RRAs are being conducted to address soil contamination at several locations within the Training Ranges and Impact Area (Ogden, 2000a). The appropriate alternative for soil remediation is dependent upon the depth and distribution of contaminants and the soil PRGs. Each potential soil remedial technology is discussed in detail in the following sections.

5.4.1 No-Action

The No Action alternative provides a baseline to which other alternatives are compared. Under this alternative, no action would be taken to implement remedial activities to control migration of COPCs away from the AOCs.

5.4.2 Excavation and Disposal or Treatment

There are at least six variations of this technology. One method is the off-site disposal of contaminants at a landfill. The other five scenarios involve on-site treatment such as Composting, Biotreatment, White Rot Fungus, Incineration, or Thermal Desorption. The depth of soil needing to be removed largely controls the feasibility and excavation costs. If the contamination is limited to the surface soil, excavation can be a relatively low-cost remedial alternative. Excavation can require extensive soil management and site restoration. Most large-scale environmental engineering firms have experience with this technology.

5.4.2.1 Landfill Disposal

On Site Landfill Disposal

Excavation with on-site disposal consists of excavation of the contaminated soil and transport to an on-site landfill for disposal. However, the existing on-site disposal facility at MMR, LF-1, has been closed. There is no other open on-site disposal facility at MMR.

Off Site Landfill Disposal

Excavation with off-site disposal consists of excavation of the contaminated soil and transport off-site to a landfill disposal site. This is proven technology but disposal costs are high if the soil is deemed a hazardous waste and it does not reduce the toxicity or volume of the contaminated materials.

5.4.2.2 Composting

Excavation and treatment with composting consists of excavation of the soil and placement into bio-piles. There are four composting methods; static-pile, in-vessel static-pile, mechanically agitated in-vessel, and windrow. In static-pile composting the excavated soil is placed in a pile under a protective shelter and mixed with a readily degradable carbon source. The pile is aerated to maintain aerobic and thermophilic conditions using forced air. Bulking agents such as sawdust, straw, bark, and wood chips, and organic amendments such as animal manure or vegetable processing waste are sometimes added. In-vessel static-pile composting is similar to static pile composting except the bio-pile is placed in a closed vessel. In a mechanically agitated in-vessel composting system, excavated soil is aerated and mixed with a carbon source in a mechanical composter. Windrow composting is similar to static-pile composting, except the compost is aerated mechanically rather than forced air. The composting process has been proven for TNT, DNT, RDX , HMX, and tetryl and is a well accepted method for explosives treatment of soil (USEPA, 1998; Preston, 1998; Craig and Sisk, 1994). Composting has been in use for over 15 years for the treatment of explosive contaminated soils. Drawbacks to the technology include: a 30 percent increase in treatment volume due to the use of bulking agents, a requirement for a large surface area in terms of managing the bio-piles, and relatively long treatment times (months, especially in cold climates) (USEPA, 1998; Preston, 1998; Craig and Sisk, 1994). The advantages of composting include the binding of degradation products to humic material and general low cost as compared to other technologies.

Treatability studies would be necessary to identify local materials that could be used for amendments for composting. Recent work at the Iowa Army Ammunition Plant (AAP) suggests that a mixture of pig manure (40%), cornstalk (40%), and soil (20%) was successful in remediating RDX, HMX, and TNT (Preston et al. 1998). TNT concentration reductions were 47%, HMX 77%, and RDX 98.7%. The initial starting explosive levels were on the order of 100 mg/kg. In comparison, the current maximum reported concentration of explosives in soil at Demolition 1 is 9.3 mg/kg of RDX. The study at the Iowa AAP evaluated mixtures of local materials due to the cost of using sawdust. Studies were also performed at the Louisiana AAP which found windrow composting to be the most cost effective composting method (USEPA, 1993). Treatability studies have also been conducted at the Umatilla Army Depot in Hermiston, Oregon and the U. S. Naval Submarine Base in Bangor, Washington (Craig and Sisk, 1994). Both treatability tests were successful and the composting technology was selected as the remedy of choice in the Record of Decision (ROD) for both sites. Estimates of treatment costs for composting have ranged from $206 to $766/ton (Craig et al. 1997). Most large-scale environmental engineering firms have experience with this technology.

5.4.2.3 Biotreatment

The technology consists of excavation of the soil, addition of water and nutrients, and placement in an ex-situ bioreactor, which can either be a closed vessel or lagoon. This technology has been proposed to remediate soils generated as part of the Rapid Response Actions being conducted under AO#3. The technology is often referred to as bioslurry. This technology allows good process control but a drawback is the potential production of degradation products that are more toxic than the starting material. Although these same degradation products are formed during composting they become bound with the humic material and become non-bioavailable. A full-scale test of this process has been conducted at the Joliet AAP (USEPA, 1993) and at the Weldon Spring Ordnance Works site (Simplot, 1998). The Joliet AAP study used an aerobic bioslurry which resulted in 99 percent removal of TNT, HMX, and RDX. TNT removal rates at the Weldon Spring Ordnance Works site using the SABREO process were 99.4 percent (Simplot, 1998). The initial TNT levels were in the 10-100 ppm range. An anaerobic bioslurry test is being conducted at the Iowa AAP. Drawbacks to the bioslurry system are the high capital and operational and maintenance costs as compared to composting, landfarming, or treatment with White Rot Fungus (Craig et al. 1997). Most large-scale environmental engineering firms will have experience with this technology.

5.4.2.4 White Rot Fungus

The technology consists of excavation of the soil and placement in a pile. White Rot Fungus is then mixed with soil, nutrients, and bulking agents. Degradation of TNT with White Rot Fungus has been reported (Fernando et al. 1990 and Berry and Boyd, 1985). A pilot scale test was conducted at the Naval Submarine Base in Bangor, Washington and resulted in a 41 percent reduction of TNT levels. No reference was found for the application of the technology to the contaminants RDX, HMX, or DNT. Although the approach has been around for about ten years its application has been limited and as a consequence only a few environmental engineering firms have the expertise for this technology. Extensive bench and pilot scale work would be necessary prior to implementing this technology at Camp Edwards.

5.4.2.5 Incineration

This technology involves excavation of the soil and then incineration either on-site or off-site. Three types of incineration devices have been used by the Army and include; rotary kiln incinerator, deactivation furnace, and contaminated waste processor. Rotary kiln incineration has been employed at the Cornhusker AAP, Louisiana AAP, Savanna Army Depot, and Alabama AAP. The explosive contaminants incinerated includes RDX, TNT, HMX, 1,2,3-TNB, 1,3-DNB, 2,4-DNT, 2,6-DNT, 2A-4,6-DNT, and tetryl. The explosive detection limits of analyzed treated soil at those sites was 1-2 mg/kg, which is higher than most of the explosive soil concentrations seen at Camp Edwards. The excavation trigger criteria for all four sites are higher than the concentrations of explosives observed at Camp Edwards. Incineration tends to be one of the more costly remedial alternatives and least publicly favorable due to concerns about air emissions. However, incineration is a demonstrated technology that is highly effective. Most large-scale environmental engineering firms have experience with this technology.

5.4.2.6 Low Temperature Thermal Desorption

Low Temperature Thermal Desorption (LTTD) consists of excavation of soil and then treatment with heat. The off-gases are then combusted in a flame oxidation unit or otherwise treated. Laboratory tests by the Army showed this technology would work for RDX, HMX, and TNT. However, the TNT degradation products, 3,5-dinitroaniline and 3,5-dinitrophenol, which were produced in the process, were found to be recalcitrant and may be toxic. This technology would only be appropriate for those sites at Camp Edwards that do not contain TNT in the soil. Data collected from the Phase I IAGS at Camp Edwards indicated the absence of TNT from soil at Demo 1. Most large-scale environmental engineering firms have experience with this technology.

5.4.3 In Situ Treatment

5.4.3.1 Landfarming

Landfarming consists of placing the soil in lined treatment plots of 12 to 18 inches deep that are then rototilled to mix nutrients, moisture and bacteria. The difference between landfarming and composting is the soil is not transported far from its source, it is not enclosed in a building, and a carbon source is not generally added. Landfarming is relatively inexpensive and simple to implement as compared to other biotechnologies. One drawback to landfarming is the large area needed for treatment. It is unclear how effective landfarming is for soils containing explosives. Bench and/or pilot scale treatability studies would likely be required to implement this technology. Most large-scale environmental engineering firms have experience with this technology.

5.4.3.2 In-Situ Vitrification

In situ vitrification (ISV) consists of heating the soil to a sufficient temperature so that it is turned into glass, rendering the contaminants immobile. Electrical current is transmitted to an electrode in the ground, which generates heat sufficient to melt the soil. A hood with negative pressure is placed over the electrodes to collect any off-gases. The technology works best in unsaturated soils. The depth of contamination impacts the implementability and cost for this technology. No information could be found on its use for explosives. However, this technology should be applicable as long as the percent level of explosives in soil is less than 10 percent. Soils with greater than 10 percent explosives are an explosive hazard. Due to the high power requirements the technology is costly to implement, although the remediation time is measured in weeks rather than years. Availability of commercial vendors for this technology is limited. Extensive bench and pilot scale work would be necessary prior to implementing this technology at Camp Edwards.

5.4.3.3 Thermal Blanket

The technology consists of using heat to destroy contaminants present in the shallow surface soil, less than 18 inches deep, in a similar manner to thermal desorption. The system consists of a series of coils placed on the ground surface that generate heat. The coils are insulated above with a layer of vermiculite and have a vapor extraction system under negative pressure to capture any off-gases. The off-gases are treated in a thermal oxidizer. This technology has been used successfully on a polychlorinated biphenyl (PCB) and dioxin contaminated site. Contaminant reduction efficiencies were 99.99 percent. The technology has not been used for surface soils contaminated with explosives but appears to be amenable for these compounds. The remediation time-period is measured in weeks. The one drawback is the large amount of electricity required, however the vendor uses a trailer mounted diesel generator. Shell Oil Company markets the technology. Extensive bench and pilot scale work would be necessary prior to implementing this technology at Camp Edwards.

5.4.3.4 Electrokinetics

Electrokinetics consists of placing vertical electrodes and treatment zones in the subsurface. The electrodes and treatment zones are installed using a large vibratory hammer, although lower-cost technologies are being evaluated for installation activities, such as jet grouting and pneumatic fracturing. The maximum viable depth is less than 100 ft below ground surface and the technology is applicable to both saturated and unsaturated zone soils. An electrical current is established between the anode and cathode. The negatively charged ions such as chloride are drawn to the cathode. Since the chloride is dissolved in water the water molecule is also dragged towards the cathode. If a contaminant is dissolved in the water, such as an explosive, it is also dragged towards the cathode along with the water. The treatment zones are installed perpendicular to the electrokinetic induced gradient. As the contaminated water is driven through the treatment zone it is remediated. The remediation system is designed such that the residence time of the contaminant in the treatment zone results in complete remediation. A series of cells are installed to cover the contaminated media. Remediation time is in the two to five year time frame depending on the desired time for remediation, which is a function of the energy expenditure. The treatment options include iron, palladized iron, carbon, or biological treatment cells. The one drawback to the technology is the large amount of electricity used and the required electrical infrastructure. Although not demonstrated for explosives the compounds of interest are ideally suited for this technology. The only commercial vendors are Electrokinetics and Monsanto although neither has applied their technologies to explosives. Extensive bench and pilot scale work would be necessary prior to implementing this technology at Camp Edwards.

5.4.3.5 Deep Soil Mixing

Deep soil mixing consists of using augers to mechanically mix soil in-situ. Various treatments are then mixed with the soil to facilitate destruction of the contaminants. The potential treatment amendments, iron, potassium permanganate, or biological organisms would need to be evaluated for explosives. The technology is limited to a depth of approximately 40-ft below ground surface. A shroud encloses the augers to capture any off-gases, which are then destroyed with a thermal oxidizer. Although the technology has been demonstrated for VOCs it has not been applied to a site with explosive contaminated soils. The technology would not be cost-effective for treating a site with only surface soil contamination, i.e. less than 2 feet or a very large site, i.e. more than 1 acre. The approach is fairly new and only a few environmental engineering firms have the expertise for this technology. Extensive bench and pilot scale work would be necessary prior to implementing this technology at Camp Edwards.

5.4.3.6 Soil Flushing

Soil flushing involves the introduction of a solvent or surfactant to solubilize and mobilize the contaminants. Soil flushing can be done in an ex-situ or in-situ mode, although most remedial actions to date have been in the ex-situ mode. Studies by Kaplan and Kaplan (1982) found that amino surfactants can precipitate TNT into an insoluble precipitate. The surfactant in this case immobilizes the TNT in the soil. However, the quantity of surfactant necessary for treatment was not cost effective.

Another possibility is to use extracted groundwater as the flushing agent (solvent) to accelerate the dissolution of explosive particulates in or on the soil and movement of the contaminants out of the soil into the groundwater. The contaminants would then be captured in a downgradient extraction well to capture and treat the contaminants. The water would be pumped to the surface, treated, and then the treated water would be sprayed over the soil. Extensive bench and pilot scale work would be necessary prior to implementing this technology at Camp Edwards as well as modeling to design a system to maintain hydraulic control. Some large-scale environmental engineering firms have experience with this technology.

5.4.3.7 Phytoremediation

Phytoremediation consists of using plants to uptake and either transform the contaminant to a non-toxic compound or immobilize it as a non-bioavailable compound. Typically, the technology is limited to explosives within the root depth of the plant, in most cases this is 1-2 feet. The technology applies to shallow soils as well as sediments in shallow water, less than 2 ft of water. Studies by Medina et al (1998) found the technology suitable for TNT although some amino-DNT, trinitrobenzene, and dinitroaniline accumulation was observed and could prove problematic. Dinitroaniline may be a toxic compound. Pilot-scale phytoremediation experiments have been conducted at the Volunteer AAP, Iowa AAP, and Milan AAP. The study at the Milan AAP found all plant species to enhance the removal of TNT from shallow groundwater. Phytoremediation of RDX and HMX was less successful but may be the result of problems in analysis (Best et al. 1997). The study at the Iowa AAP found negligible removal of TNT and RDX by the plants in surface water, however the result suggest a plant microorganism symbiotic relationship which results in microbiological reduction of TNT and RDX (Best et al. 1997). This technology would not be applicable for groundwater at this site due to its depth below surface. Remediation of the soil is slow with this technology. The approach is fairly new and only a few environmental engineering firms have the expertise for this technology. Extensive bench and pilot scale work would be necessary prior to implementing this technology at Camp Edwards.

5.4.3.8 Capping

This technology consists of placing a low permeability cap (clay, asphalt, geomembrane liner, or combination) to decrease the infiltration of precipitation through the contaminated soil. This approach would require fate-and-transport modeling to assess if the reduction in infiltration is sufficient to lower the amount of contaminants reaching the aquifer. Control of surface water/precipitation must be included with this option. Most large-scale environmental engineering firms have experience with this technology.

5.5 Potential Groundwater Remedial Technologies

Groundwater remediation may be required at Demo 1, the Central Impact Area, and the Southeast Corner of the Ranges. Potential groundwater remedial technologies are subdivided into hydraulic containment and in-situ categories and are discussed below.

5.5.1 No-Action

Under this alternative, the AOC would be allowed to continue in its present condition without any efforts to control the migration of explosives in groundwater. This alternative provides a basis for assessing the effects of taking remedial action, and provides an environmental baseline against which other alternatives are compared.

5.5.2 Hydraulic Containment

In a hydraulic containment system groundwater is pumped to the surface from one or more wells, treated, and discharged (i.e. to surface water or reinjected into the aquifer). Single or multiple wells can be used, with a higher efficiency possible with multiple extraction wells, i.e. lower pump rates for the same capture zone width. Various methods are used to treat the water, depending on the contaminant and discharge limit. Pump-and-treat has been viewed with growing disfavor for the remediation of contaminated groundwater due to its inability to achieve remedial goals and its high operational and maintenance cost (NRC, 1994 and USEPA, 1992). A growing trend is the use of pump-and-treat as a hydraulic containment tool to isolate a source area (Nyer et al. 1996). In this context, the manner in which pump-and-treat is considered for the Training Ranges and Impact Area is as a hydraulic containment system. The system could utilize vertical or horizontal wells. The wells could be placed at the leading downgradient edge of the groundwater contamination area or through the center of the area of contamination. Other groundwater collection options could include the use of barrier walls or reinjection wells to funnel the area of groundwater contamination to a smaller area. This would be done to minimize the amount of water needed to be pumped from the aquifer and treated. Later the hydraulic containment system could be augmented or replaced with additional wells or some other remedial technology to perform hotspot remediation at the source. The use of subsurface drains such as a French Drain would not be practical at the AOCs due to the depth to groundwater and the high groundwater flow velocities.

Treated water can also be reinjected into the aquifer to enhance gradient control, reinjected into the vadose zone, or applied to the ground surface to enhance the dissolution of explosives. Reinjection can be accomplished with a number of different techniques such as reinjection wells, infiltration galleries of wells, trench infiltration galleries, subsurface drains, or landsurface application. In this scenario the amount of water extracted to obtain a given capture zone width can be much less than stand-alone extraction wells since the reinjection wells can be used to push water to the extraction wells. The reinjection points could be laterally on either side of the area of contamination, at the extraction well location to minimize groundwater withdrawals, in the source area to enhance dissolution and flushing of contaminants through the vadose zone, or upgradient of the source area to increase the groundwater flow velocities in the aquifer. Groundwater flow modeling would be necessary to optimize the system to the best arrangement of extraction and reinjection wells. Although initial capital costs are higher than for extraction only system, due to the need for installation of an injection system and additional infrastructure, long term operational and maintenance treatment costs are lower due to the smaller volume of water pumped and treated.

5.5.2.1 Carbon Treatment

The pump-and-treat technology consists of passing the extracted groundwater through a treatment bed or reactor vessel containing granular activated carbon (GAC). The technology has been demonstrated for explosives (HMX, RDX, and TNT) at several sites, including the Pantex Plant in Amarillo, Texas, Milan AAP in Milan, Tennessee, and Badger AAP in Wisconsin (Fleming et al. 1996; Bricka and Fleming, 1995; and Hinshaw et al. 1987). Since these are the same contaminants found at Camp Edwards there would be no need for a pilot test or treatability study. Some limited testing and evaluation of chemical data would be necessary to evaluate the need for pretreatment of water to remove iron, manganese, and hardness to avoid fouling the GAC. If desired, the technology is readily implementable for full-scale remediation.

Recent studies conducted at the Cornhusker AAP evaluated the removal of RDX, trinitrobenzene (TNB), TNT, and HMX from water (Fleming et al. 1996). The tests included the evaluation of six GACs, two carbonaceous resins, one polymeric resin, and two organophillic clays. The polymeric resin and organophillic clays were not effective in reducing contaminant concentrations below the effluent limit of 2 ug/L. GAC was found to satisfactorily remove the explosives of interest with some differences in efficiency between the various types of GAC. Studies have also been conducted at the Milan AAP, Burlington Iowa AAP (Hinshaw et al. 1987), Radford AAP, Lone Star AAP, Kansas AAP, Joliet AAP, and Picatinny Arsenal (Bricka and Fleming, 1995). In all AAP cases, the initial concentrations of explosives in water exceeded 100 mg/L. These studies found GAC to perform satisfactorily for the removal of explosives.

One drawback to the GAC treatment technology is the creation of contaminated carbon. Management of the carbon as a waste is can be expensive. Regeneration of the carbon loaded with explosives using base hydrolysis has been evaluated and looks promising (Heilmann et al. 1996 and Knezovich et al. 1994). Direct treatment of wastewater with base hydrolysis, however is not economical (Heilmann et al. 1996). Other approaches are to wash the carbon using heated water and ethanol to remove the contaminants and then run the effluent through a microbiological consortium (Knezovich et al. 1994), regeneration using acetone (Fleming et al. 1996), and regeneration using thermal oxidation. Regenerated carbon costs are approximately $55,000/year and virgin carbon approximately $87,000/year for a 700 gpm system (Fleming et al. 1995). The system discussed by Fleming et al. (1995) was treating groundwater with explosive contaminant levels up to 3 orders of a magnitude higher than what has been observed at Camp Edwards. This technology is widespread and most large-scale environmental engineering firms have experience with this technology. A treatability test would be necessary to further evaluate any GAC regeneration process before implementation at Camp Edwards.

5.5.2.2 Aqueous-Phase Bioreactor Treatment

The bioreactor treatment process consists of passing extracted groundwater through a reactor containing a microbiological consortium to degrade the contaminants. It has been well established in the literature that TNT is susceptible to biodegradation under both aerobic and anaerobic conditions and RDX and HMX are suceptible to biodegradation under anaerobic conditions in the soil column (Brannon et al. 1998; Brannon et al. 1997; Bruns-Nagel et al. 1996; Haigler and Spain, 1996; Bradley and Chapelle, 1995; Bradley et al. 1994; Unkefer et al. 1990; and Soli, 1973). Limits on the technology include the volume of water to be treated and the possibility of production of recalcitrant TNT degradation products such as the DNTs. Tyndall and Vass (1993) claim to have isolated a bacterium that results in complete destruction of TNT but the effectiveness of this bacterium has not been tested for RDX and HMX. Most pump-and-treat bioreactor applications have been limited to 10 gpm or less pumping rates. Most large-scale environmental engineering firms will have experience with this technology. Extensive bench and pilot scale work would be necessary prior to implementing this technology at Camp Edwards.

5.4.2.3 Zero-valent Iron or Pallidized Iron

The technology consists of passing the extracted groundwater through a reactor vessel containing zero-valent iron or palladized iron. This is a promising potential treatment option based on the chemical structure of the explosives in groundwater at Camp Edwards. Limited laboratory work has been performed by Oak Ridge National Laboratory, U.S. Army Corps of Engineers, Waterways Experiment Station, and others (McGrath, 1998; Korte, 1998; Agrawal and Tratynek, 1995; Agrawal et al. 1995; Agrawal and Tratynek, 1994; and Schwarzenbach et al. 1994). Advantages are low operational and maintenance costs and no need for off-site disposal of media, unlike carbon. The reaction involves the destruction of the nitroaromatic compound so there is no buildup of contaminants on the reactive media. By-products released into water include, nitrate, aromatic amines, hydroxylamines, nitroso compounds, and hydrogen. One potential drawback is the creation of intermediate byproducts that may be as toxic as the starting compound, such as hydroxylamines and nitroso compounds. Thus, iron treatment may need to be combined with a biological process, which can further reduce the aromatic amines, hydroxylamines, and nitroso compounds. Additional potential drawbacks include clogging of media over time or reduced treatment efficiency and need for regeneration of iron/palladium surface to remove salt precipitates, typically calcium or ferrous carbonates. EnviroMetal Technologies Inc. holds the license on the patent and is the commercial provider of the zero-valent iron system for volatile organic compounds and the Research Corporation for palladized iron covering all organic compounds. The patents do not appear to cover explosives. Extensive bench and pilot scale work would be necessary prior to implementing this technology at Camp Edwards.

5.5.2.4 Catalytic Oxidation

The technology consists of passing the extracted groundwater through a catalytic oxidation unit. This is a potential treatment option based on the chemical structure of the explosives in groundwater at Camp Edwards, but a treatability test would be required to prove its feasibility. However, catalytic oxidation units are more appropriate for higher contaminant concentrations than seen at Camp Edwards. Typically, a catalytic oxidation unit has a fairly high capital and long term operational and maintenance costs. Numerous commercial vendors are available for the catalytic oxidation units. Most large-scale environmental engineering firms have experience with this technology.

5.5.2.5 Ultraviolet Oxidation

The technology consists of passing the extracted groundwater through an ultraviolet photoxidation unit or oxidizing the water with ozone. Pilot-scale tests of this technology have been performed at the Kansas AAP, Crane AAP, Iowa AAP, Holston AAP, and Picatinny Arsenal (Fleming et al. 1995 and LeFaivre and Peyton, 1994). The study at Picatinny Arsenal found that RDX could be reduced below 1 ug/L from a starting concentration of 4.5 ug/L (Flemming et al. 1995). Ultraviolet oxidation with ozone was more efficient than ultraviolet oxidation alone. However, unknown and unidentifiable compounds were observed in the effluent stream. These studies found that ultraviolet oxidation could destroy TNT, RDX, HMX, and tetryl. However, TNB accumulates if an insufficient residence time is used. TNB is a degradation product of TNT. Studies of water from the Bangor U. S. Naval Submarine Site indicated ultraviolet photoxidation was cost competitive with other treatment technologies, although a number of recalcitrant TNT degradation products were observed in the effluent stream (LeFaivre and Peyton, 1994). Full-scale treatment systems can range up to 2,000 gpm.

Full-scale operational and treatment costs are estimated at $55,000 to $90,000/year with a unit cost of approximately $700,000 (Fleming et al. 1995) for a 5 gpm system treating RDX at a concentration of less than 5 ug/L. Several commercial vendors market this technology: Ultrox Inc., Peroxidation Systems Inc., Solarchem Inc., Excalibur Enterprises Inc., Nutech Inc., and Purus Inc. This technology can have higher than anticipated operational and maintenance costs over the long term, due to equipment failure as result of fouling issues. Most large-scale environmental engineering firms have experience with this technology. Extensive bench and pilot scale work would be necessary prior to implementing this technology at Camp Edwards.

5.5.3 In-Situ Treatment

5.5.3.1 Impermeable Barrier Wall

The technology consists of installing an impermeable barrier such as sheet piling, clay, or cement slurries to change groundwater flow directions. The barriers could be installed upgradient of the source area to deflect groundwater around the contaminated source. A barrier wall installed downgradient of a source area is generally used to intercept and funnel a plume or cut off a source area. In this configuration the barrier wall is usually used in conjunction with an extraction well(s) or reactive barrier, i.e. “gate”. The effect of the barrier wall is to funnel the water into a smaller region so less water is needed to be extracted and treated. Another concept is to complete a four-sided barrier around the source area using either an impermeable cap to restrict recharge via precipitation, or using a well in the center to maintain hydraulic control. Barrier walls can be constructed using cement-bentonite slurry, soil bentonite slurry, steel sheet piling, high-density polyethylene liner, or various polymer slurries. Given the site geology, the concept would have to be for a hanging barrier wall, possibly coupled with some hydraulic control, i.e limited pumping since the uppermost confining unit is a till at 300+ ft below ground surface. A hanging barrier wall is so named since it is not keyed into a lower impermeable or confining geologic unit such as clay or bedrock. The depth to groundwater outside of the kettle hole at Demo 1 would be approaching the limits of the technology in terms of installation. Drawbacks to barrier walls are the high capital cost associated with the installation of deep walls and proving that the barrier wall is working. Most large-scale environmental engineering firms have experience with this technology.

5.5.3.2 Reactive Barrier Wall

The technology consists of installing a permeable barrier to treat contaminants in-situ. Usually, the technology is coupled with an impermeable barrier wall and in this configuration is called a "funnel-and-gate". The treatment medium is usually zero-valent iron but other materials are possible and are being evaluated such as biological consortia, bimetals, zeolites, peat, etc. As is the case with an impermeable barrier wall, there is a high capital cost associated with the installation of a deep reactive barrier wall. A significant unknown with reactive barrier walls is the performance over the long term of the reactive media. The oldest reactive barrier wall has been operational less than five years. Laboratory work has shown that clogging due to the formation of precipitates can potentially be a significant issue (Horney et al. 1995). The approach is fairly new and only a few environmental engineering firms have expertise with this technology. Extensive bench and pilot scale work would be necessary prior to implementing this technology at Camp Edwards.

5.5.3.3 In-Situ Recirculation Wells

The technology consists of two horizontal wells where water is extracted at one well and then reinjected at another. The horizontal wells can be placed one above the other or parallel to each other at the same depth. They can also be placed perpendicular to the groundwater flow direction to intercept a plume for containment or they can be placed down the axis of plume for reduction of mass. The advantage of such a system is that groundwater plumes are typically narrow in the vertical direction making a horizontal well better suited for the contaminant distribution and thus more efficient than a vertical well. A thin narrow contaminated region is ideally suited for this type of technology.

The concept was recently proven at a Department of Energy (DOE) site in Ohio using in-situ treatment canisters for treatment of a mixed waste plume (Korte et al. 1998). The treatment canisters were placed in the extraction well so all contaminants were treated below the ground surface. The system was engineered such that the treatment canisters were recoverable and the treatment media could be replaced or regenerated if necessary. Another in-situ recirculation well was installed at a DOE site in Florida. This system consisted of injection of microbes in one well and extraction at another well. The extracted water was inoculated and then reinjected to create a circulation cell. Both in-situ recirculation wells were successful in removing contaminant mass.

The primary disadvantage of this technology is that it has not been demonstrated to be effective for explosives. It is possible that the demonstrated recirculation technologies could be modified to incorporate a treatment technology for remediation of explosives. The treatment media would need to be tested and would likely include carbon, iron, palladized iron, biological, or possibly peat alone or in some combination. Extensive bench and pilot scale work would be necessary prior to implementing this technology at Camp Edwards. No commercial vendors are available for this technology in an aquifer containing explosive contaminants.

Figures

Tables

5.5.3.4 *In-Situ Chemical Oxidation*

In-situ chemical oxidation consists of the introduction of chemical oxidizers into the aquifer to destroy organic contaminants. Typically, this technology involves the installation of well(s) whereby the oxidizer is introduced into the aquifer through the well. The oxidizer is usually used to treat a hot spot rather than a large dilute contaminant plume, due to the cost of treatment. Typical oxidizers used in groundwater treatment include ozone, hydrogen peroxide, dichromate, and potassium permanganate. The use of ozone and hydrogen peroxide in combination is called peroxone. It was reported that peroxone has been tested in a treatability study to remove TNT (Zappi, 1998). One drawback of using peroxone is that the oxidizer is nonselective, oxidizing contaminants as well as naturally occurring carbonates and bicarbonates. The more carbonate present in the groundwater the more oxidizer needed to treat a given mass of contaminants, since some oxidizer will react with the carbonate and thus not be available for contaminant destruction. Given the low alkalinity of groundwater at Camp Edwards this should not be a major issue. Although the treatment method has not been tested on RDX or HMX, the chemical structure of these compounds suggest that they should be susceptible to chemical oxidation. The approach is fairly new and only a few environmental engineering firms have expertise with this technology. Extensive bench and pilot-scale work would be necessary prior to implementing this technology at Camp Edwards.

5.5.3.5 *Monitored Natural Attenuation*

Monitored Natural Attenuation (MNA) consists of the reduction of contaminant mass through non-engineered activities. The principal reliance is upon destruction of the contaminant through natural, non-engineered biological or oxidation-reduction processes. This approach has been demonstrated for TNT, which is known to degrade (Balasco, 1996).

The only ROD utilizing MNA for explosives is at the Sierra Army Depot in Herlong, California (Balasco et al. 1996). In this case, the principal explosive contaminant was TNT. The selection of MNA at this site was based on the following; negligible horizontal and vertical plume movement, no current or future receptors, limitations of pump-and-treat, cost, reevaluation of site-specific data, and ongoing routine monitoring. A FS of MNA conducted at the Joliet AAP found evidence to support a MNA remediation approach for TNT, RDX, and TNB (Pennington et al. 1998). The study found that all three compounds were being attenuated and therefore MNA could be considered as an alternative for that site.

Implementing a MNA approach at Camp Edwards would require collection of additional geochemical data to assess the rate and process of biological reduction of TNT. Groundwater modeling would also be necessary to estimate travel times to receptors and predicted maximum concentrations at the compliance point. Modeling would have to be performed to determine the effect of dilution and dispersion on the RDX and HMX contaminant mass to see if this is a viable option given the distance to the Camp Edwards property boundary. The approach is fairly new and only a few environmental engineering firms have expertise with this technology.

5.6 Potential UXO Remedial Technologies

Potential remedial alternatives for UXO have not been developed in detail as part of this FSWP due to limited existing characterization of the nature and extent of the potential problem. If it is determined that UXO poses a risk to groundwater, appropriate alternatives will be evaluated that remove the UXO of concern from the environment while minimizing any release of contaminants to the environment. Alternatives to address UXO that pose a threat to groundwater will include disposal options such as in-situ detonation, on-site detonation or disposal at a remote location, and off-site detonation or disposal at an approved facility. These technologies will be developed and evaluated in more detail in the Development and Initial Screening of Alternatives Report based on the conclusions of the site characterization activities.

5.7 Feasibility Study Data Requirements

The likely data requirements for potential soil and groundwater remedial technologies and the proposed timeframe for obtaining them is discussed in the following two sections. Identification of the FS data requirements is a planning step to ensure that the FS process proceeds without delay.

The characterization efforts for each AOC or OU will provide the data to satisfy the requirements listed below to allow development and initial screening of remedial alternatives for soil, groundwater and UXO.

- Identify COCs and range of concentrations
- Determine PRGs
- Delineate the depth and areal extent of contamination
- Quantify the volume and/or mass of contaminated media

Following that characterization, the most significant data requirement for potential soil and groundwater remedial technologies is the need to complete bench and/or pilot scale treatability studies. Treatability studies typically range in duration from weeks to several months depending on the type and complexity. The need for treatability studies for the technologies will be assessed throughout the site characterization and development and screening of alternatives. Treatability studies, if necessary, will be proposed in the Post-Screening Investigations Work Plan.

5.7.1 Soil Remedial Technologies

Table 5-3 identifies FS data requirements to enable evaluation of potential soil remedial alternatives. The nature and importance of the data and the timeframe in which they will be obtained is discussed below. Some data are required for most potential alternatives and others are specific to a single technology.

Table 5-4 provides a summary of existing soil treatability data.

Bench and/or pilot scale treatability studies will be conducted after the initial screening of alternatives, if necessary, and prior to the detailed evaluation of alternatives. The initial screening narrows down the potential alternatives to those that provide the best balance of the evaluation criteria. The bench and/or pilot studies are then conducted for the technology or technologies that are most likely to best meet the objectives. If a technology is identified as a strong candidate alternative for an AOC, treatability studies could be conducted earlier in the process.

Bench and pilot scale treatability studies are currently planned for biotreatment of soils contaminated with explosives from the RRA AOCs in accordance with the Draft Work Plan for Rapid Response Action and Draft Release Abatement Measure Plan (Ogden, 2000a). Data from these studies would also apply to alternatives that employ biodegradation, such as composting, white rot fungus and landfarming.

Several physical and chemical soil properties are planned to be collected as part of the fate and transport modeling activities in accordance with the Draft Statement of Work for MMR Site Specific Fate & Transport Measurements Task 0200 (Ogden, 2000f). The soil properties to be obtained include bulk density, pH, fraction of organic carbon, cation exchange capacity, extractable iron, and grain size distribution. Grain size data have been estimated by USGS as part of their modeling efforts. Additional grain size data and pH can be collected relatively quickly if necessary for site-specific purposes. Soil moisture content has been collected as part of the IAGS. The existing data for these parameters are adequate to conduct the FS. Site specific data for these parameters will be collected as needed during the execution of the FS and RD as remedy selection nears for an AOC or OU.

Desorption kinetics of the COCs would be required if phytoremediation was identified as a viable alternative in the initial screening of alternatives. In general, this involves determining how the contaminants are desorbed from soil so that they are available for plant uptake. This type of information will be collected as part of the proposed Fate and Transport Modeling (Ogden, 1999d).

Osmotic permeability and electrical conductivity would be evaluated if electrokinetics were determined to be a viable alternative for an AOC or OU after completion of the Development and Initial Screening of Alternatives Report. Site-specific evaluations would need to be conducted to determine the properties to determine the feasibility and reasonable cost.

Typical thermal parameters depending on the specific technology and/or facility include heating value of waste, total halogens, oversized, and restricted contaminants. The specific requirements will be determined if incineration or low temperature thermal treatment is selected as a potential alternative.

Specific waste characterization parameters such as toxicity characteristic leaching procedure (TCLP), corrosivity, ignitability, and reactivity typically are required for off-site treatment and/or disposal. Existing site characterization data are typically used to determine potential applicability and a reasonable cost for these alternatives. As additional data are collected and potential alternatives are developed and screened, the need for specific waste characterization data will be assessed.

5.7.2 Groundwater Remedial Technologies

Table 5-5 identifies FS data requirements to enable evaluation of potential groundwater remedial alternatives. The nature and importance of the data and the timeframe in which they will be obtained is discussed below.

Table 5-6 presents a summary of existing groundwater treatability data for each of the AOCs.

Site specific groundwater models will likely be utilized to evaluate the implementability, effectiveness and cost of potential groundwater remedial technologies. The models would be developed as an extension of the proposed fate and transport modeling (Ogden, 1999d).

Similar to potential soil technologies, the need for bench/pilot scale studies will be assessed throughout the FS process. For hydraulic containment technologies, bench and/or pilot scale treatability studies would be required to evaluate most of the treatment technologies for the collected groundwater. The specific need for these studies will be documented in the Development and Initial Screening of Alternatives Report and planned in the Post-Screening Investigations Work Plan.

Hydraulic conductivity data are required for all potential alternatives. An appropriate range of hydraulic conductivity values is currently available. The data have been generated by the USGS for groundwater modeling and by AFCEE for designing groundwater remediation systems. The USACE will generate additional data as part of evaluating potential water supply well locations. The currently available data in conjunction with the planned fate and transport modeling are adequate for completing the FS. Site specific data may be required prior to design of a groundwater remedial alternative. A site-specific aquifer pumping test may be required to design some of the potential groundwater remedial alternatives.

Grain size data have been estimated by USGS as part of their groundwater modeling efforts. pH has been typically measured in the field as part of the IAGS. The existing data for these parameters are adequate to conduct the FS. Site specific data for these parameters will be collected as needed during the execution of the FS and RD as remedy selection nears for an AOC or OU.

Biological parameters would be required to evaluate the potential effectiveness of MNA and to assess the potential for fouling problems associated with other technologies. Typical parameters that may be required are dissolved oxygen, oxidation reduction potential (ORP), nitrate/nitrite, phosphate, sulfate/sulfide, total and dissolved iron and manganese, methane, carbon dioxide, temperature, pH, conductivity, hardness, alkalinity, ammonia-nitrogen, biological oxygen demand (BOD), chemical oxygen demand (COD), and total suspended solids. Some of these parameters have been and/or are being collected as part of groundwater sampling conducted at the Training Ranges and Impact Area. The specific needs for biological parameters will be assessed throughout the FS process. Collection and analysis of specific biological parameters will be added to the ongoing groundwater sampling program where appropriate.

5.7.3 UXO Remedial Technologies

Completion of the site characterization activities described in Sections 2.4.5 and 3.5 is required prior to completing the FS Report for UXO. FS data requirements beyond the site characterization activities are currently unknown but are not anticipated to be extensive. The identification of potential FS data requirements for UXO technologies will be continuously evaluated throughout the performance of site characterization activities. This process will allow for the early identification and collection of data requirements to expedite the remediation process.

6.0 PROJECT OPERATIONS PLAN

Many of the required elements of the Project Operations Plan (POP) have been previously submitted by Ogden Environmental and Energy Services for the National Guard Bureau and approved by USEPA Region I. The POP will reference these documents where appropriate. As new requirements are identified, they will be added via addendum to the existing documents, as has been the practice in the past.

6.1 Site Management Plan

The work to be completed under the FS/RD/RA components of AO#3 is multifaceted and will likely involve several different teaming structures to complete the entire process. The details of the Site Management Plan (SMP) for each of the components (FS, RD and RA) will be different and based on the type of work being conducted. The critical information required for a SMP for ongoing and planned investigation activities is documented in previously submitted plans. Due to the uncertainties associated with future RD and RA activities, the project team structure and responsibilities are currently only provided for the FS component.

6.1.1 FS Organization and Management Team

The team established to conduct the FS component for the Training Ranges and Impact Area at Camp Edwards provides continuity with the technical aspects of the IAGS and public involvement process. The key personnel and their responsibilities are provided below.

Program Officer. Lieutenant Colonel Joe Knott, National Guard Bureau (NGB). LTC Knott is responsible for providing the overall direction, coordination and leadership for all activities at the Training Ranges and Impact Area at Camp Edwards. He is the primary point of contact for the NGB.

Program Director. Ben Gregson, LSP, Massachusetts Army National Guard (MAARNG). Mr. Gregson has the day-to-day responsibility of managing the FS components for the MAARNG. He ensures overall compliance of FS submittals with AO#3 requirements and coordinates activities with regulatory agencies and the public.

Ogden Environmental and Energy Services

Program Director. Rob Clemens. Mr. Clemens is fully dedicated to MMR and has complete authority to commit Ogden resources and resolve issues. He responsible for staff assignments, subcontractor selections and overall Ogden team performance.

Program Manager. Marc Grant, PE. Mr. Grant's key responsibility is maintaining the quality and consistency of work products and work efforts. His specific responsibilities include:

- Primary point of contact with the NGB and MAARNG
- Organize and staff projects
- Select, train and supervise project managers
- Establish and oversee operating procedures
- Program/Project review

FS Manager. Mark Applebee. Mr. Applebee is responsible for the technical performance and adherence to schedules and budgets for the FS activities. His specific responsibilities include:

- Plan, schedule, and manage FS tasks
- Communicate with MAARNG and NGB
- Ensure technical compliance with AO#3 requirements
- Supervise day-to-day conduct of the work
- Integrate the efforts of all supporting disciplines and subcontractors
- Oversee the preparation of all reports and plans
- Provide for QC and quality review during performance of the work

6.1.2 Identification of Contractors and Subcontractors

Ogden Environmental and Energy Services is the Supervising Contractor for AO#3. Due to the unknowns surrounding the RD and RA components of AO#3, identification of subcontractors will be made at a later date. Contractor and subcontractor arrangements for site characterization activities will continue in the same manner as is ongoing for the IAGS. USA is the UXO subcontractor and DL Maher is the drilling subcontractor.

Specific subcontractors for the FS component of AO#3 have not been identified at this time. For the FS component, subcontractors will most likely be required to conduct bench/pilot scale treatability studies to provide data for evaluation of alternatives. Notification of the identity and qualifications any proposed subcontractors will be made at least seven (7) days in advance of performing any work under AO#3.

6.1.3 General Site Management Items

Ogden currently has a fully operational Field Office at MMR. The office has been used the past three years to direct and manage ongoing IAGS field efforts.

Investigation derived waste (IDW) and other wastes generated during FS activities (if any) will be managed in accordance with currently established procedures.

Data generated for the AOCs will continue to be managed in accordance with the Air Force-Wide Environmental Resources Program Information Management System (AFW-ERPIMS. AFW-ERPIMS is a relational database used to store and manage data collected for environmental projects.

6.2 Sampling and Analysis Plan

6.2.1 Field Sampling Plan

The only currently identified additional investigation for which a Field Sampling Plan (FSP) can be developed is for deep soils at Demo 1. Additional investigations may be required to adequately characterize the nature and extent of contamination at the AOCs. As discussed in Section 3, it is likely that additional downgradient groundwater investigations will be required for the Central Impact Area, but the details of the required investigations can not be identified at this time. A FSP will be developed for all new investigations required for the Training Ranges and Impact Area at Camp Edwards. The FSPs will be prepared and submitted for review in the same manner as the IAGS documents.

The FSP for the soil explorations at Demo 1 is provided below.

6.2.1.1 Demo 1 – Field Sampling Plan

Demo 1 is located north of Forestdale Road and south of the Impact Area, near the current H Range at MMR. Demo 1 includes a natural 1-acre topographic depression, or kettle hole, that is approximately 45 feet below the surrounding grade. An access road surrounds the topographic low and circumscribes a 7.4-acre area (Figure 6-1). The bottom of the topographic low is a flat, cratered area. Low areas and individual craters remain wet for most of the winter and spring. The depth to groundwater from the base of the depression is about 40 feet. A concrete observation bunker was constructed on the north-facing slope of the south side of the topographic low, but has since been removed. Demolition activities appear to have been concentrated in the topographic low, based on historic maps and interview information. According to interview information, demolition activities in the topographic low did result in the intermittent ejection, or “kick out”, of explosives and/or demolition materials from the depression into the surrounding area.

Several soil investigations have been conducted at Demo 1 and are summarized in the Final IAGS Technical Team Memorandum 99-2, Deep Soil Sampling of Demolition Area 1 (Ogden, 2000g). Tech Memo 99-2 recommended that additional deep soil borings be installed east of the existing borings.

6.2.1.2 Sampling Objectives and Rationale

The objective of the new borings is to characterize the remainder of the unsaturated zone within the topographic depression, where there is the highest probability of a continuing source of contamination. These new data in conjunction with existing soil data will allow quantification of the nature and extent of soil contamination at Demo 1.

6.2.1.3 Sampling & Analysis Methods for Soils

Soil borings will be extended using a hollow-stem auger drill rig. Lanes for drill rig access will be intrusively cleared of all magnetic anomalies to a depth of two feet. Figure 6-1 indicates the proposed boring locations. The proposed nine borings will each be advanced using a down-hole magnetometer for UXO clearance to a depth of 12 feet. Soil samples will be collected for explosives on 1-foot intervals from 3 to 16 ft bgs at 9 locations. Based on the results from these samples, up to four of these borings will be sampled on 2-ft intervals from 16 ft to the water table, approximately 44 ft. Samples will be analyzed for explosive compounds using USEPA Method 8330.

Sample collection will be consistent with MMR Standard Operating Procedures (SOPs), and the Ogden Health and Safety Guidelines, Attachment A: Field Guide to High Explosives. Proposed sampling points will be flagged for magnetic anomalies prior to sampling, and sampling points adjusted if necessary to avoid anomalies.

In addition to field samples, Quality Assurance/Quality Control (QA/QC) samples will be collected as described in the QA/QC Plan (Ogden, 1999e). This includes field duplicates at the rate of 10% (rounded to the next whole number) of the field samples, field blanks at the rate of one per sampling event per water source, and equipment rinsates at the rate of 1 per day per decontamination method.

6.1.2.4 Sample Identification

Soil samples may be collected from borings depending based on photoionization detector (PID) field screening results. Soil samples will be uniquely identified with an Ogden sample ID that contains a reference to the sample location (boring number) and the sample depth. The following is an example of the sample ID:

SB0010BAD

The sample ID is broken down in the following example, to describe each of the components:

SB - 0010 - AA - A

SB	Indicates that the sample being collected is a soil boring sample.
0010	Indicates the boring number from which the sample was collected.
AA	Indicates the depth from which the sample was collected. Depth character will be "AA" for the first sample (regardless of depth), "BA" for the second sample, etc.
A	Indicates the type of sample.

A	Original Sample
D	Duplicate Sample
E	Equipment Rinsate
F	Field Blank
T	Trip Blank

For example, SB0010BAD is a soil boring duplicate sample from soil boring 10, from the second sample depth within the boring.

6.2.2 Quality Assurance Project Plan (QAPP)

Ogden will conduct all sampling and analysis efforts in accordance with existing QAPP protocols. The last full submittal approved by the USEPA was the QA/QC Plan Revision 3 (Ogden, 1999e). Additional revisions (4-6) have been submitted in the form of change pages through the present. The existing QA/QC Plan will be updated as necessary in the future to meet the requirements of AO#3 as has been done in the past.

6.3 Health and Safety Plan (HASP)

Ogden will conduct all field operations in accordance with existing HASP (Ogden, 1997a) prepared for use in implementing previous work efforts at MMR. Addenda will be prepared and submitted for any required new activities.

6.4 Public Involvement Support Plan

In March 2000 a Draft Public Involvement Plan (PIP) was jointly prepared and submitted to the USEPA by the National Guard Bureau and the Massachusetts Army National Guard (MAARNG, 2000). The PIP was prepared specifically for activities to be conducted in accordance with the requirements of AO#3. The PIP builds off the existing Impact Area Review Team (IART) and ensures public involvement in all work required by AO#3.

7.0 LONG TERM MONITORING PLAN

7.1 Objectives

The objectives of the long term monitoring are to monitor impacted media to determine the potential changes in the nature and extent of the contamination and to provide data to evaluate seasonal variability, climatological influence, fate and transport, and background levels for COPCs identified at each AOC. This monitoring data will be used ensure that site characterization data is updated as necessary throughout the FS and RD process.

7.2 Groundwater

The Draft Interim Long Term Groundwater Monitoring Plan, Year 2000 (Ogden, 2000e) delineates the plan for monitoring groundwater at Camp Edwards. The Interim Long Term Groundwater Monitoring (LTGM) Plan in conjunction with ongoing monitoring well installation and groundwater sampling programs provides a site wide systematic approach to continuing proactive groundwater monitoring. This program will provide the necessary data to characterize the nature and extent of contamination and to evaluate the risks to human health and the environment at the AOCs.

The primary objective of the Interim LTGM Plan is to monitor the distribution of explosives in groundwater at and downgradient of release areas identified during the IAGS. These data will be reviewed on an annual basis to determine if:

- the type of explosives detected in groundwater changes, or
- the areal distribution of explosives increases or decreases.

The Interim LTGM Plan also addresses infrequently detected VOCs, pesticides, herbicides, and the two metals molybdenum and antimony.

Another objective of the Interim LTGM Plan is to monitor the quality of potable and non-potable supply wells. This aspect of the Plan was implemented as an interim measure pursuant to the Draft Workplan for Completion of Phase I Activities (Ogden, 1998b).

The final consideration is to evaluate the effectiveness of source removal actions. This objective will become more significant after the first few years of the Interim LTGM Plan, as remediation efforts are completed.

The rationale for wells selected and analysis to be performed for the calendar year 2000 is based on the accumulated groundwater quality data since inception of the IAGS. Based on these same initial data, the second year of interim monitoring, and groundwater quality data from ongoing studies, the Interim LTGM Plan will likely be modified for the year 2001. With each revision to the Plan the most appropriate monitoring wells will be included to continually evaluate groundwater quality conditions in the aquifer, and to protect existing and proposed drinking water supplies. For each AOC, the groundwater monitoring will, at a minimum, continue until the issuance of the 100% RD.

As analytical data accumulates over the next few years, statistical methods will become a more valued tool for evaluating the seasonal variability, climatological influence, fate and transport, and background levels. Population statistics or similar evaluations may be conducted, as part of the Year 2001 Plan, to evaluate the less frequently detected compounds. Specific statistical and/or mathematical techniques to be used to evaluate the data will be identified in subsequent LTGM Plans.

7.3 Surface Water and Sediment

No surface water or sediment that has been impacted by contamination from the AOCs identified in Appendix B of AO#3 has been identified to date. Therefore, long term monitoring of surface water and sediment is not proposed at this time. If subsequent investigations indicate impacts to surface water and/or sediment a long term monitoring plan will be developed as needed.

8.0 SCHEDULE

Gantt chart schedules for each AOC are provided in Figures 8-1 to 8-4. Each schedule shows site characterization activities that are underway under the IAGS Program and the FS activities proposed under AO#3. The dependencies between the two types of activities are illustrated in the Gantt charts and described in Section 8.1 for each AOC. The Gantt chart columns indicate for each activity whether its completion is proposed as an enforceable milestone, the remaining duration in working days, and start and finish dates. USEPA has approved the enforceable milestones for site characterization activities except where noted in Section 8.1. The schedules will continue to be updated on a monthly basis and will be included with all future FS/RD/RA document submittals.

RD and RA activities are not included in the schedules at this time. The remedial alternative selected for the AOCs or OUs directly impacts the durations for completion of the design and remediation. Schedules for the RD and RA components will be added at a later date when potential remedial alternatives are better identified. The anticipated required tasks, subtasks and duration (where appropriate) for RD and RA activities are provided in Section 8.2.

Figure 1-2 depicts the relative timing and flow of activities required to complete the remediation at an AOC or OU. Figure 1-3 identifies the tasks, objectives and associated documents for each of the components of the remediation process.

There are several factors that can influence the overall schedule for completion of the FS at an AOC; (1) ability to overlap timelines of steps, (2) extent of post-screening investigations required (if necessary) and (3) ability to make use of previously generated data and evaluations from one AOC for similar efforts at other AOCs.

The schedules currently provide for overlapping of the execution timelines for the completion of site characterization and initiation of the development and initial screening of alternatives for a specific AOC or OU. The degree to which this overlap occurs is dependent upon the overall understanding of the conceptual site model and the existing level of characterization available. Overlapping of the activities is ongoing as evidenced by the identification of potential technologies for soil and groundwater for the AOCs. This process is conducted in an iterative fashion where information flows back and forth between the two activities. Therefore, the technologies may need to be updated as new site characterization information is obtained and interpreted.

Post-screening investigations may not be required. The need for collection of additional data will be based upon the type of alternatives that are developed and pass the initial screening. Typically, innovative and undemonstrated technologies require bench and/or pilot scale studies to help determine their applicability to the specific AOC. Previously demonstrated technologies may not require additional data collection prior to the detailed evaluation of alternatives.

It is likely that evaluations and assessments conducted for one AOC could be useful in completing similar evaluations and reports for other AOCs. This could condense the timelines for some tasks.

The National Guard is committed to expediting the process to select an appropriate remedial alternative for the AOCs while maintaining adherence to technical requirements, effective coordination with regulatory agencies, and appropriate public involvement. AOCs will be subdivided into OUs, where appropriate, to accelerate the remedy selection and implementation process for OUs where characterization is nearer completion. The schedules for some of the later AOCs and/or OUs may be able to be condensed if similar media and contaminants of concern are identified as those evaluated for previous sites.

8.1 Proposed Site Characterization and Feasibility Study Schedule

Proposed schedules for each of the AOCs provided in Figures 8-1 to 8-4 are discussed in the following sections.

8.3.1 Demo 1

Site Characterization activities include nature and extent investigations specific to Demo 1 (activities 00110 - 00200) and fate and transport modeling that is generally applicable to all areas (activities 07100 - 07140). The nature and extent investigations include soil and groundwater studies pursuant to implementation of the Response Plan for Demolition Area 1 (Ogden, 1999b) (activities 00110 to 00150), geophysics investigations pursuant to implementation of the munitions survey (activities 00160 - 00170), and the additional deep soil investigation proposed in this FSWP (activities 00180 - 00200). The deep soil investigation will be the last of these activities, and will be initiated on approval of this FSWP. The completion of the draft report for the deep soil investigations is proposed as the final nature and extent information needed to complete the Development and Initial Screening of Alternatives Report for the Soil OU. The initial screening report for the Soil OU also requires PRGs to be developed from the fate and transport modeling. The modeling is in the critical path for the Soil OU FS because it is scheduled to be completed after the nature and extent investigations.

FS activities include completion of this workplan (activities 20110 - 20140) and, for each OU, completion of the Development and Initial Screening of Alternatives Report, post-screening planning and investigations if needed, and the FS. Screening reports for the soil and groundwater OUs are initiated upon approval of the FSWP, but completion of the screening report for the Soil OU relies on the completion of the fate and transport modeling as indicated above. Therefore, the FS activities for the Groundwater OU are expected to be completed ahead of the comparable activities for the Soil OU.

8.1.2 Central Impact Area

Site Characterization activities include nature and extent investigations specific to the Central Impact Area (activities 00210 - 00282), including the munitions survey of High Use Target Area 1 (HUTA1) (activities 01110 - 01195), and fate and transport modeling that is generally applicable to all areas (activities 07100 - 07140). The nature and extent investigations include soil and groundwater studies currently underway pursuant to implementation of the Final Phase II(a) Response Plan for Impact Area RDX Detections in Groundwater (Ogden, 2000b) (activities 00210 - 00270), and an additional Response Plan (activities 00272 - 00282) that is expected to be needed based on preliminary results from the current work. The schedule for the additional Response Plan required to delineate the nature and extent of downgradient groundwater has not been previously reviewed or accepted by USEPA. The Guard proposes to begin planning for this Response Plan in early May 2000, as the current fieldwork is nearing completion. The completion of the draft report for the additional Response Plan (activity 00276) is proposed as the final characterization information needed to complete the Development and Initial Screening of Alternatives Report and is proposed as an enforceable milestone (00278). Other site characterization data needed for the screening report include draft results of the HUTA1 study and fate and transport modeling, but neither of these activities is currently in the critical path.

FS activities include completion of this workplan (activities 20110 - 20140), the Development and Initial Screening of Alternatives Report (22110 - 22140), post-screening planning and investigations if needed (22150 - 22200), and the FS (22210 - 22240). The Screening Report is initiated upon workplan approval, but completion is dependent on nature and extent studies as indicated above.

8.1.3 Southeast Corner of the Ranges

Site Characterization activities include nature and extent investigations for the J-2 Range (activities 00310 - 00397) and the J-1/J-3/L Ranges (activities 00400 - 00497), and fate/transport modeling that is generally applicable to all areas (activities 07100 - 07140). The nature and extent investigations for the J Ranges are currently being planned. Since these are the first detailed investigations of the J Ranges, the Guard expects that these studies may not be conclusive regarding the nature and extent of contamination. Therefore, additional delineation of contaminants has been included in the schedules for the J-2 Range (activities 00392 – 00397) and the J-1/J-3/L Ranges (activities 00492 – 00497). The schedules for these additional studies have not been previously reviewed or accepted by USEPA. The Guard proposes to begin planning for each additional study as the initial fieldwork is nearing completion. The completion of the draft report for the additional studies (activities 00394 and 00494) are proposed as the final site characterization information needed to complete the Development and Initial Screening of Alternatives Report and are proposed as enforceable milestones (00395 and 00495). The results of fate and transport modeling are also needed to complete the screening report, but this activity is not currently in the critical path. A Response Plan (Ogden, 2000c) is currently underway for the J-1/J-3 Range area based on groundwater detections of RDX (activities 00400 - 00405).

FS activities include completion of this workplan (activities 20110 - 20140), the Development and Initial Screening of Alternatives Report (23110 - 23140), post-screening planning and investigations if needed (23150 - 23200), and the FS (23210 - 23240). The Development and Initial Screening of Alternatives Report is initiated upon workplan approval, but completion is dependent on nature and extent studies as indicated above.

8.1.4 UXO

Site Characterization activities include geophysics investigations for Demo Area 1 (activities 00160 - 00170), the J-2 Range (00365 - 00367), the J-1/J-3 Range (00465 - 00467), the Gun/Mortar Positions (00515), the HUTA 1 (01110 - 01195), the Water Bodies (01210 - 01220), the Slit Trench (01310 - 01320), and fate and transport modeling that is generally applicable to all areas (activities 07100 - 07140). The FS activities are divided into two Operable Units; the HUTA1, and all other areas. USEPA has directed that the draft FS for HUTA1 (24160) is due 45 days from completion of the draft HUTA1 report (01170). The Development and Initial Screening of Alternatives Report for HUTA1 is initiated upon workplan approval, but completion is dependent on completing the fate and transport modeling (07140). Based on the modeling task timeline and the USEPA requirement for the draft FS, preparation of the final screening report and the draft FS will overlap for HUTA1. No post-screening investigations are envisioned for HUTA1, as the site characterization is expected to provide all of the information needed for the FS.

For the non-HUTA1 areas, FS activities include the screening report (24210 - 24240), post-screening planning and investigations if needed (24250 - 24300), and the FS (24310 - 24340). The screening report is initiated upon workplan approval, but completion is dependent on fate and transport modeling (07140) and completion of the various geophysics investigations (00170, 00367, 00467, 00515, 01220, 01320). The modeling is in the critical path as it has the longest timeline of the predecessors for the screening report.

8.2 Remedy Selection Process

The FS provides the basis for the decision-makers to select the remedy, but does not identify the proposed remedy. The selection of the proposed remedy will be reached through a collaborative process among the Guard, USEPA, MADEP and the public that takes place throughout the site characterization and FS process via review of documents, public and technical meetings, and other means of communication such as fact sheets and poster board sessions.

Figures

Tables

The Remedy Selection Plan will be prepared and submitted concurrent with the Final FS Report and upon approval will be distributed for public comment. The Remedy Selection Plan will summarize the characterization data and FS Report and identify the proposed Remedial Alternative that provides the best balance of the evaluation criteria for an AOC or OU. Upon incorporation of agency and public comments, a Decision Document will be prepared. The Decision Document details the specific components and performance objectives of the remedy and provides an official record of the remedy selection.

AO#3 does not require preparation of a Remedy Selection Plan. However, it is included in the remediation process to facilitate public participation in the remedy selection process.

8.3 Remedial Design and Remedial Action

RD activities will be initiated upon selection of a remedial alternative for an AOC or OU. The anticipated activities to be conducted for the RD and RA and proposed due dates are outlined in Table 8-1.

The duration of the RA for an AOC or OU will depend on several factors, such as the COCs, PRGs, volume/mass to be remediated, and the selected remedy. The due dates identified in Table 8-1 are the same as those specified in AO#3. The Guard intends to meet or exceed the timelines specified in AO#3. Detailed schedules for the RD and RA will be submitted as part of the RD and RA Work Plans.

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ACRONYMS AND ABBREVIATIONS

2,4-DANT	2,4-diamino-4-nitrotoluene
2,4-DNT	2,4-dinitrotoluene
2,6-DNT	2,6-dinitrotoluene
2A-DNT	2-amino-4,6-dinitrotoluene
4A-DNT	4-amino-2,6-dinitrotoluene
AAP	Army Ammunition Plant
AFCEE	Air Force Center for Environmental Excellence
ANG	Air National Guard
AO	Administrative Order
AO#3	Administrative Order Number 3 (SDWA 1-2000-0014)
AOC	Area of Concern
ARARS	Applicable or relevant and appropriate requirements
AFW-ERPIMS	Air Force Wide-Environmental Resources Program Information Management System
B-#	soil boring identification number
BBM	Buzzards Bay Moraine
BEHP	bis(2-ethylhexyl) phthalate
bgs	below ground surface
BOD	Biological Oxygen Demand
BTEX	benzene, toluene, ethylbenzene and xylenes
bwt	below water table
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act of 1980
COC	contaminant of concern
COD	Chemical Oxygen Demand
COPC	contaminant of potential concern
CS	chemical spill
Demo 1	Demolition Area 1
DO	dissolved oxygen
DOE	Department of Energy
DP-#	drive point identification number
DWEL	Drinking Water Equivalent Level
DUS	dynamic underground stripping
EDB	ethylene dibromide
EOD	Explosive Ordnance Disposal
EPA	United States Environmental Protection Agency, Region 1
FS	Feasibility Study
FS-#	fuel spill identification number
FSP	Field Sampling Plan
FSWP	Feasibility Study Work Plan
ft	feet
GAC	granular activated carbon
GW	groundwater

ACRONYMS AND ABBREVIATIONS

HA	USEPA lifetime health advisory
HASP	health and safety plan
HE	high explosives
HMX	octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine
HUTA	High Use Target Area
IAGS	Impact Area Groundwater Study
IART	Impact Area Review Team
IDW	investigation derived waste
IRP	Installation Restoration Program
ISV	in-situ vitrification
LE	low explosives
LRWS	Long Range Water Supply
LTGM	Long Term Groundwater Monitoring
LTTD	low temperature thermal desorption
MAARNG	Massachusetts Army National Guard
MADEP	Massachusetts Department of Environmental Protection
MCL	federal maximum contaminant level
MCP	Massachusetts Contingency Plan
MCPP	2-methyl-4-chlorophenoxyacetic acid
mg/kg	milligram per kilogram
MIDAS	Munitions Items Disposition Action System
mm	millimeter
MMR	Massachusetts Military Reservation
MNA	Monitored Natural Attenuation
mph	miles per hour
MPP	Mashpee Pitted Plain
MW-#	monitoring well identification number
NGB	National Guard Bureau
ngvd	national geodetic vertical datum
NRC	Nuclear Regulatory Commission
NTU	nephlometric turbidity units
Ogden	Ogden Environmental and Energy Services
ORP	oxidation/reduction potential
OU	operable unit
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PCE	tetrachloroethene
PDA	photo-diode array
PETN	pentaerythritol tetranitrate
PID	photoionization detector
PIP	Public Involvement Plan
POP	Project Operations Plan
PRG	preliminary remediation goal

ACRONYMS AND ABBREVIATIONS

PVC	poly vinyl chloride
QAPP	Quality Assurance Project Plan
QA/QC	Quality Assurance/Quality Control
RA	Remedial Action
RAO	remedial action objective
RD	Remedial Design
RDX	hexahydro-1,3,5-trinitro-1,3,5-triazine
ROD	Record of Decision
RRA	Rapid Response Action
SDWA	Safe Drinking Water Act
SM	Sandwich Moraine
SMCL	federal secondary maximum contaminant level
SMP	Site Management Plan
SOP	Standard Operating Procedure
SOW	Statement of Work
SVOC	semi-volatile organic compounds
TCE	trichloroethylene
TCLP	toxicity characteristic leaching procedure
TNT	2,4,6-trinitrotoluene
TOC	total organic carbon
ug/L	micrograms per liter
ug/kg	micrograms per kilogram
US Army	United States Department of the Army
USGS	United States Geological Survey
UXO	unexploded ordnance
USACE	United States Army Corps of Engineers
USAF	United States Air Force
USCG	United States Coast Guard
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
USN	United States Navy
VA	Veterans Administration
VOC	volatile organic compound
WWII	World War II

Figures

Tables

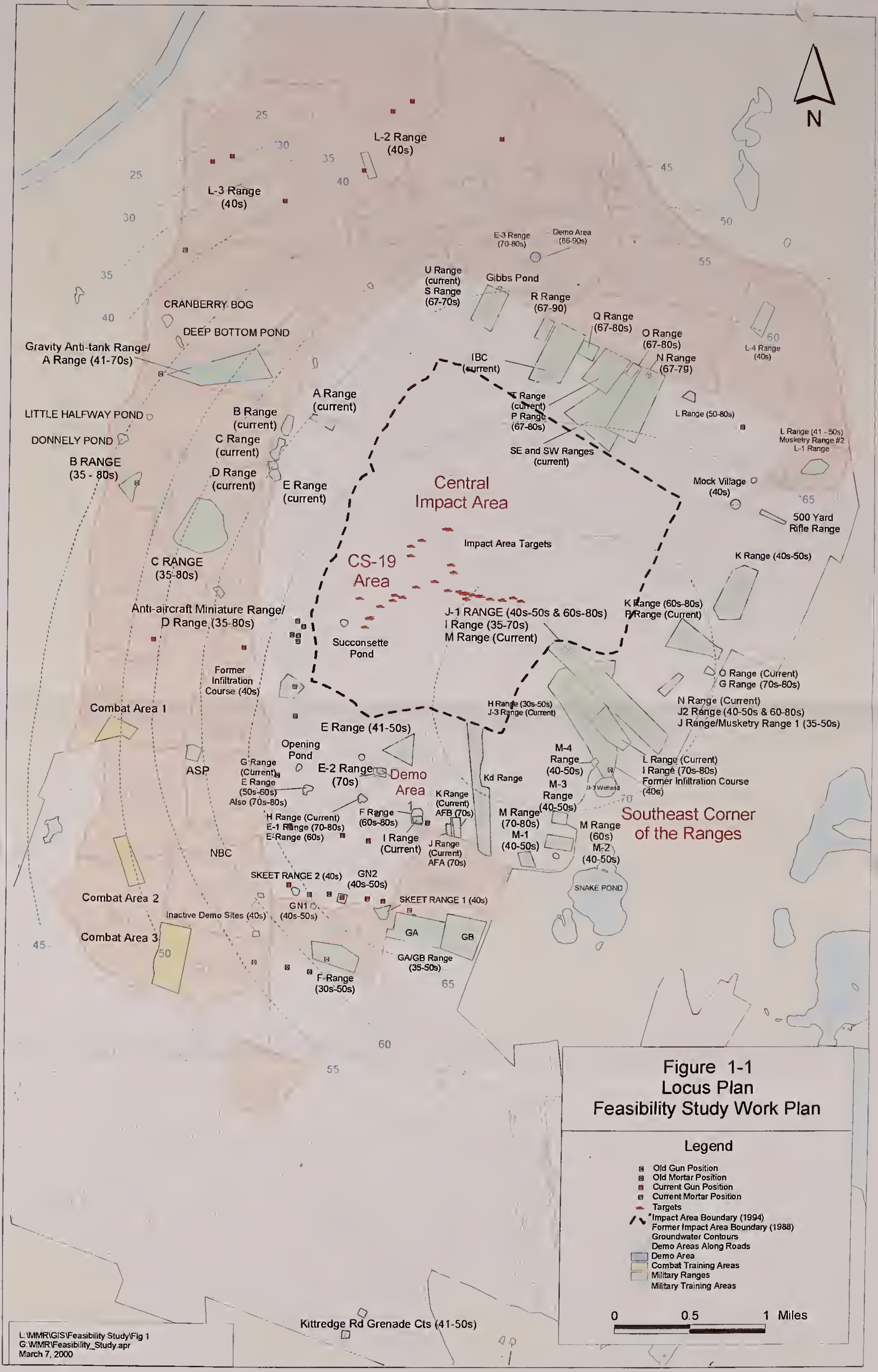

Figure 1-1
Locus Plan
Feasibility Study Work Plan

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G:\MMR\Feasibility_Study.apr
March 7, 2000

Figure 1-2
Remediation Process Flow Diagram
Feasibility Study Work Plan

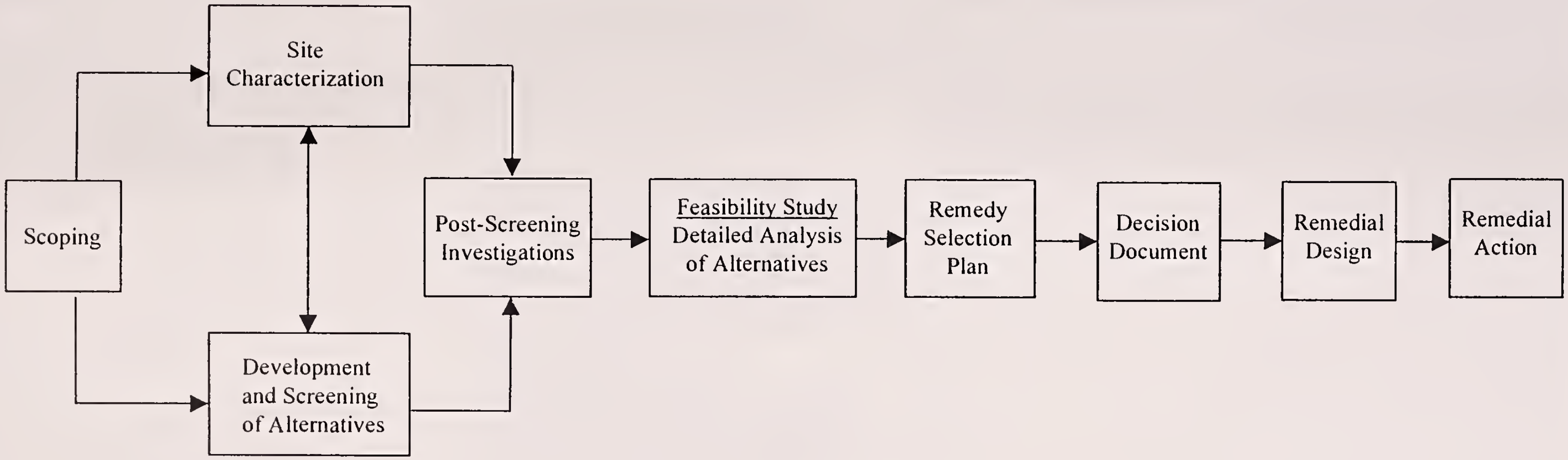
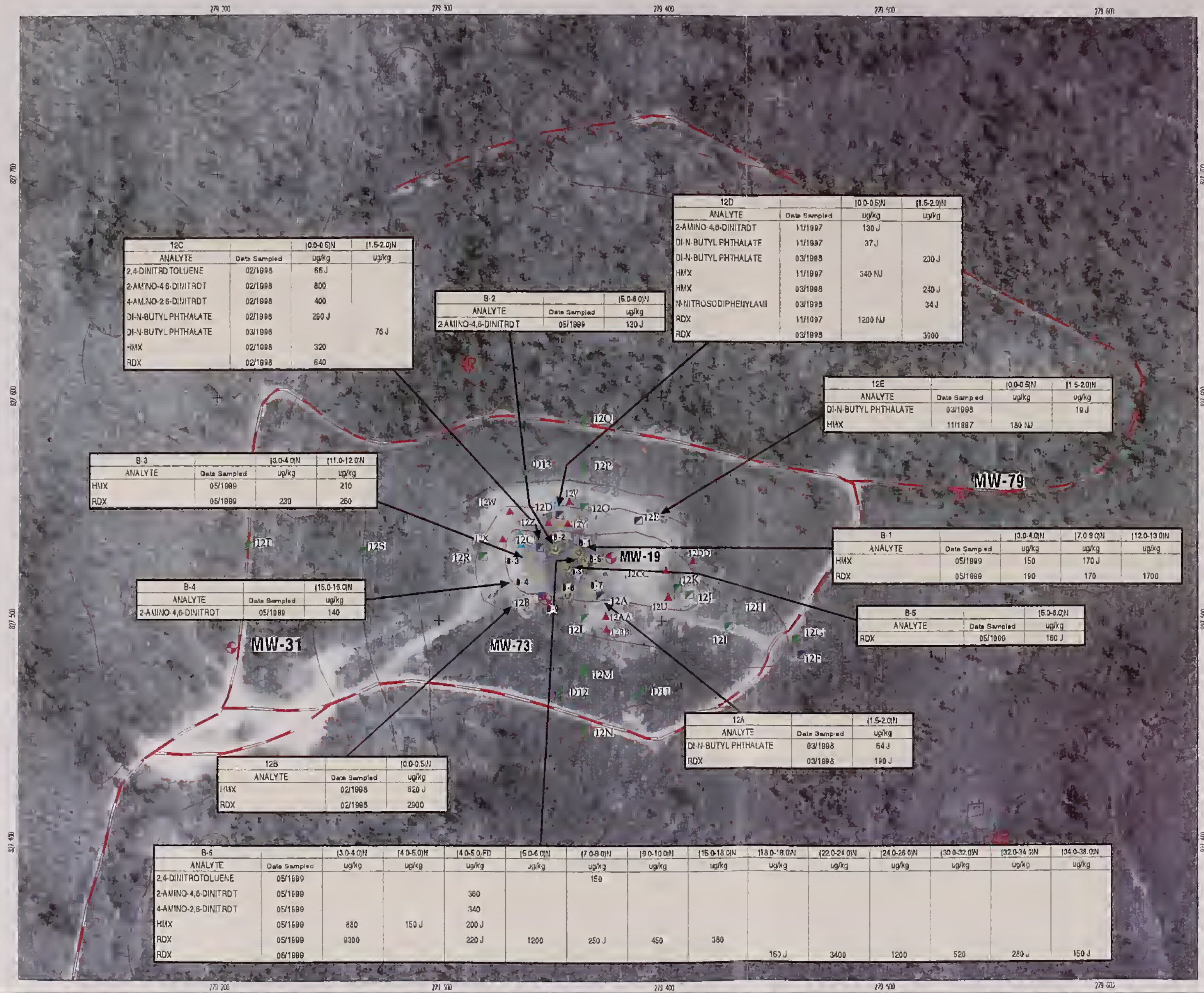


Figure 1-3
REMEDIATION PROCESS SUMMARY
FEASIBILITY STUDY WORK PLAN

	Scoping of the Site Characterization and Feasibility Study	Site Characterization	Development and Screening of Alternatives	Post-Screening Investigations
Tasks	Collect and analyze existing data Identify initial AOCs and OUs Identify initial Data Quality Objectives (DQOs) Establish technical review team (IART) Prepare project plans	Prepare Field Sampling Plans (FSPs) Field investigations Sample analysis/validation Data evaluation Risk evaluation	Develop Remedial Action Objectives (RAOs) Develop General Response Actions Define volumes or areas of affected media Identify potential technologies Evaluate process options Screen technologies Assemble technologies into alternatives Screen alternatives as necessary	Literature searches Bench and/or pilot scale treatability studies Collection of add'l characterization data
Objectives	Develop overall management strategy	Define nature and extent of contamination Identify Contaminants of Concern (COCs) Identify Preliminary Remediation Goals (PRGs)	Develop an appropriate range of alternatives	Provide sufficient data to perform detailed evaluation of alternatives
Documents	Public Participation Plan (MAARNG, 2000) QA/QC Plan (Ogden, 1999e) Health and Safety Plan (Ogden, 1997a) Final Action Plan (ETA, 1997) Feasibility Study Work Plan	Site-Wide Fate and Transport Modeling (Ogden, 1999d) Long Term Monitoring Plan (Ogden, 2000e) Demo 1 Final Action Plan (ETA, 1997) FSP for Area 12 - Demo 1 (Ogden, 1997b) Draft Completion of Work Report (Ogden, 1998a) Workplan for Completion of Phase I (Ogden, 1998b) Demo 1 Response Plan (Ogden, 1999b) TM 99-2 Deep Soil Sampling Results (Ogden, 2000e) Draft Demo 1 Soil&GW Report (Ogden, Jun 00) FSWP for Add'l Deep Soil Sampling (Ogden, Apr 00) Draft Soil Report (Ogden, Dec 00) Central Impact Area Final Action Plan (ETA, 1997) Draft Completion of Work Report (Ogden, 1998a) Workplan for Phase II(a) Activities (Ogden, 1999f) Phase II(a) Response Plan (Ogden, 2000b) Draft Central Impact Area Report (Ogden, Oct 00) Additional Response Plan (Ogden, Jul 00) Draft Response Plan Report (Ogden, Feb 01) Southeast Corner of the Ranges Final Action Plan (ETA, 1997) Draft Completion of Work Report (Ogden, 1998a) RDX Response Plan (Ogden, 2000c) J-2 Range Workplan (Ogden, Apr 00) J-1, J-3, L Ranges Workplan (Ogden Apr 00) Unexploded Ordnance (UXO) Geophysics Presentations (TetraTech) Gun/Mortar (Apr 00) Demo 1 (Jun 00) Water bodies (Jul 00) Slit Trench (Jul 00) J-2 Range (Oct 00) HUTA 1 (TetraTech) Draft Workplan (Apr 00) HUTA 1 Draft Report (May 01)	Evaluation of Remediation Technologies for Demo 1 (Ogden, 2000f) Development and Initial Screening of Alternatives Report	Post-Screening Investigation Work Plan

Figure 1-3
REMEDIATION PROCESS SUMMARY
FEASIBILITY STUDY WORK PLAN

	Feasibility Study Detailed Evaluation of Alternatives	Remedy Selection Plan	Decision Document	Remedial Design (RD)	Remedial Action (RA)
Tasks	Further define alternatives Analyze alternatives against criteria Compare alternatives against each other	Summarize characterization data Summarize Feasibility Study	Summarize characterization data Summarize Feasibility Study Summarize remedy selection process Identify components of remedy	Pre-design investigations (1) Plans and specifications Design analysis Cost Estimate	Construct and operate remedy Complete performance evaluation
Objectives	Provide decision makers with relevant information needed to select a remedy	Provide summary of data and evaluations for public comment	Document & approve selected remedy	Provide design information to ensure the remedy will meet the performance standards	Remediate AOC or OU to meet approved performance standards
Documents	Feasibility Study Report	Remedy Selection Plan	Decision Document	RD Work Plan and POP (1) 60% Complete RD 100% RD	RA Work Plan and POP (1) Weekly RA Progress Reports Operation and Maintenance Plan Revised POP (if necessary) Environmental Monitoring Plan RA Completion Report Demonstration of Compliance



12C		(0.0-0.5)N	(1.5-2.0)N
ANALYTE	Date Sampled	ug/kg	ug/kg
2,4-DINITRO TOLUENE	02/1998	66 J	
2-AMINO-4,6-DINITROT	02/1998	800	
4-AMINO-2,6-DINITROT	02/1998	400	
DI-N-BUTYL PHTHALATE	02/1998	260 J	
DI-N-BUTYL PHTHALATE	03/1998		76 J
HMX	02/1998	320	
RDX	02/1998	640	

B-2		(5.0-6.0)N
ANALYTE	Date Sampled	ug/kg
2-AMINO-4,6-DINITROT	05/1999	130 J

12D		(0.0-0.5)N	(1.5-2.0)N
ANALYTE	Date Sampled	ug/kg	ug/kg
2-AMINO-4,6-DINITROT	11/1997	130 J	
DI-N-BUTYL PHTHALATE	11/1997	37 J	
DI-N-BUTYL PHTHALATE	03/1998		200 J
HMX	11/1997	340 NJ	
HMX	03/1998		240 J
N-NITROSODIPHENYLAMI	03/1998		34 J
RDX	11/1997	1200 NJ	
RDX	03/1998		3900

12E		(0.0-0.5)N	(1.5-2.0)N
ANALYTE	Date Sampled	ug/kg	ug/kg
DI-N-BUTYL PHTHALATE	03/1998		19 J
HMX	11/1997	180 NJ	

B-3		(3.0-4.0)N	(11.0-12.0)N
ANALYTE	Date Sampled	ug/kg	ug/kg
HMX	05/1999		210
RDX	05/1999	230	260

B-1		(3.0-4.0)N	(7.0-8.0)N	(12.0-13.0)N
ANALYTE	Date Sampled	ug/kg	ug/kg	ug/kg
HMX	05/1999	150	170 J	
RDX	05/1999	190	170	1700

B-4		(15.0-16.0)N
ANALYTE	Date Sampled	ug/kg
2-AMINO-4,6-DINITROT	05/1999	140

B-5		(5.0-6.0)N
ANALYTE	Date Sampled	ug/kg
RDX	05/1999	160 J

12A		(1.5-2.0)N
ANALYTE	Date Sampled	ug/kg
DI-N-BUTYL PHTHALATE	03/1998	64 J
RDX	03/1998	190 J

12B		(0.0-0.5)N
ANALYTE	Date Sampled	ug/kg
HMX	02/1998	620 J
RDX	02/1998	2900

B-6		(3.0-4.0)N	(4.0-5.0)N	(4.0-5.0)FD	(5.0-6.0)N	(7.0-8.0)N	(9.0-10.0)N	(15.0-16.0)N	(18.0-18.0)N	(22.0-24.0)N	(24.0-26.0)N	(30.0-32.0)N	(32.0-34.0)N	(34.0-38.0)N
ANALYTE	Date Sampled	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg
2,4-DINITROTOLUENE	05/1999					150								
2-AMINO-4,6-DINITROT	05/1999			380										
4-AMINO-2,6-DINITROT	05/1999			340										
HMX	05/1999	880	150 J	200 J										
RDX	05/1999	9300		220 J	1200	250 J	450	380						
RDX	06/1999								160 J	3400	1200	520	280 J	150 J

MMR
Groundwater Study

LEGEND

●	Groundwater Wells
◩	Soil Grids - Round 1
◩	Soil Grids - Round 2
	Soil Borings
▲	Anomaly Soil Samples
ug/kg	Micrograms Per Kilogram
NJ	Tentatively Identified, Estimated Quantity
J	Estimated Quantity
FD	Field Duplicate
N	Normal Environmental Sample

NOTE: All soil sampling locations shown but results are only reported for Borings (B-1 through B-9) and Round 1 Soil Grids (12A-F)
IMAGE DATE: 1994
All sample depth measurements are in feet

BASEMAP LEGEND

▬	Water Bodies
▬	Roads
- -	Paths
—	3 Meter Contours
▲	C4 Residuals
○	Smoke Grenade

LOCATION MAP

NOTES & SOURCES

Chemical database last queried on: Mar 16 12:34
Map coordinates: Stateplane, NAD83, Zone 4151, Meters

ORTHOPHOTOGRAPHY: 1:5000 digital black & white orthophotos
Source: MASSGIS; Resolution: 1/2 meter Date Flown: 1994

TOPOGRAPHY: 3 meter contours generated from digital terrain models (DTMs)
Source: MASSGIS

TITLE

Detected Contaminants of Potential Concern
(COPCs) in Soil
Demo Area 1
Feasibility Study Work Plan

N

0 150
FEET
0 46
METERS

FIGURE
2-1

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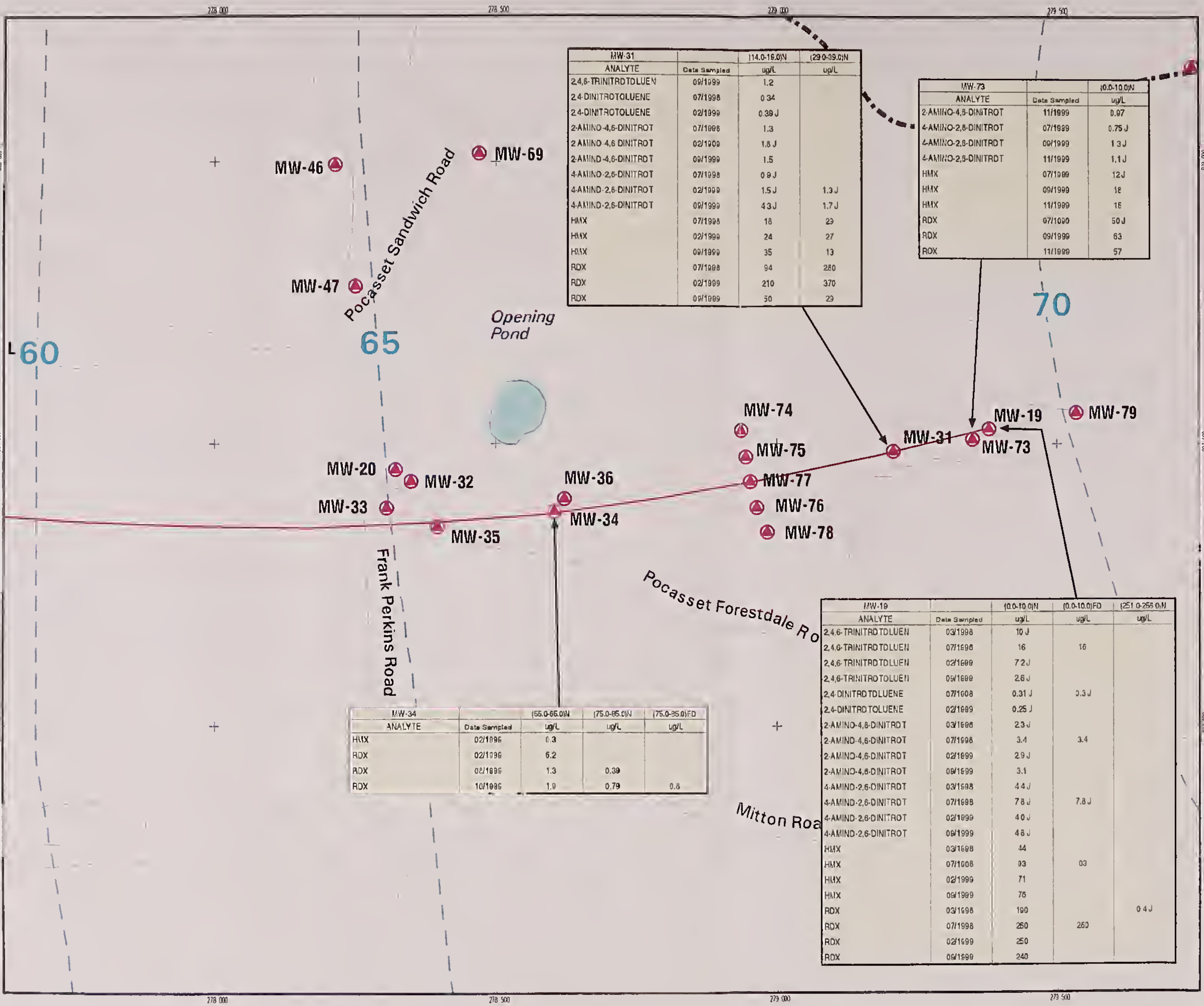

MW-31		(14.0-16.0)N	(29.0-39.0)N
ANALYTE	Date Sampled	ug/L	ug/L
2,4,6-TRINITROTOLUEN	09/1999	1.2	
2,4-DINITROTOLUENE	07/1998	0.34	
2,4-DINITROTOLUENE	02/1999	0.39 J	
2-AMINO-4,6-DINITROT	07/1998	1.3	
2-AMINO-4,6-DINITROT	02/1999	1.8 J	
2-AMINO-4,6-DINITROT	09/1999	1.5	
4-AMINO-2,6-DINITROT	07/1998	0.9 J	
4-AMINO-2,6-DINITROT	02/1999	1.5 J	1.3 J
4-AMINO-2,6-DINITROT	09/1999	4.3 J	1.7 J
HMX	07/1998	18	29
HMX	02/1999	24	27
HMX	09/1999	35	13
RDX	07/1998	94	280
RDX	02/1999	210	370
RDX	09/1999	50	29

MW-73		(0.0-10.0)N
ANALYTE	Date Sampled	ug/L
2-AMINO-4,6-DINITROT	11/1999	0.97
4-AMINO-2,6-DINITROT	07/1999	0.75 J
4-AMINO-2,6-DINITROT	09/1999	1.3 J
4-AMINO-2,6-DINITROT	11/1999	1.1 J
HMX	07/1999	12 J
HMX	09/1999	18
HMX	11/1999	16
RDX	07/1999	50 J
RDX	09/1999	63
RDX	11/1999	57

MW-34		(55.0-65.0)N	(75.0-85.0)N	(75.0-85.0)FD
ANALYTE	Date Sampled	ug/L	ug/L	ug/L
HMX	02/1996	0.3		
RDX	02/1996	6.2		
RDX	08/1996	1.3	0.39	
RDX	10/1996	1.9	0.79	0.6

MW-19		(0.0-10.0)N	(0.0-10.0)FD	(251.0-256.0)N
ANALYTE	Date Sampled	ug/L	ug/L	ug/L
2,4,6-TRINITROTOLUEN	03/1998	10 J		
2,4,6-TRINITROTOLUEN	07/1998	16	16	
2,4,6-TRINITROTOLUEN	02/1999	7.2 J		
2,4,6-TRINITROTOLUEN	09/1999	2.6 J		
2,4-DINITROTOLUENE	07/1998	0.31 J	0.3 J	
2,4-DINITROTOLUENE	02/1999	0.25 J		
2-AMINO-4,6-DINITROT	03/1998	2.3 J		
2-AMINO-4,6-DINITROT	07/1998	3.4	3.4	
2-AMINO-4,6-DINITROT	02/1999	2.9 J		
2-AMINO-4,6-DINITROT	09/1999	3.1		
4-AMINO-2,6-DINITROT	03/1998	4.4 J		
4-AMINO-2,6-DINITROT	07/1998	7.8 J	7.8 J	
4-AMINO-2,6-DINITROT	02/1999	4.0 J		
4-AMINO-2,6-DINITROT	09/1999	4.8 J		
HMX	03/1998	44		
HMX	07/1998	93	93	
HMX	02/1999	71		
HMX	09/1999	76		
RDX	03/1998	190		0.4 J
RDX	07/1998	260	260	
RDX	02/1999	250		
RDX	09/1999	240		

MMR
Groundwater
Study

LEGEND

▲	Groundwater Wells
ug/L	Micrograms Per Liter
J	Estimated Quantity
FD	Field Duplicate
N	Normal Environmental Sample

NOTE: Results for recently installed MWs 74-79 are not reported.

All sample depth measurements are in feet below watertable

BASEMAP LEGEND

- MW-19 Regional Forward Particle Track
- Groundwater Contours
- MMR Boundary
- Impact Area Boundary
- Roads

LOCATION MAP

NOTES & SOURCES

Chemical database last queried on: Mar 16 12:34

Map coordinates: Stateplane, NAD83, Zone 4151, Meters

TITLE

Detected Explosive Compounds in Groundwater
Demo Area 1
Feasibility Study Work Plan

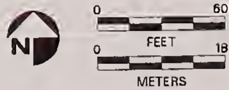

FIGURE
2-2

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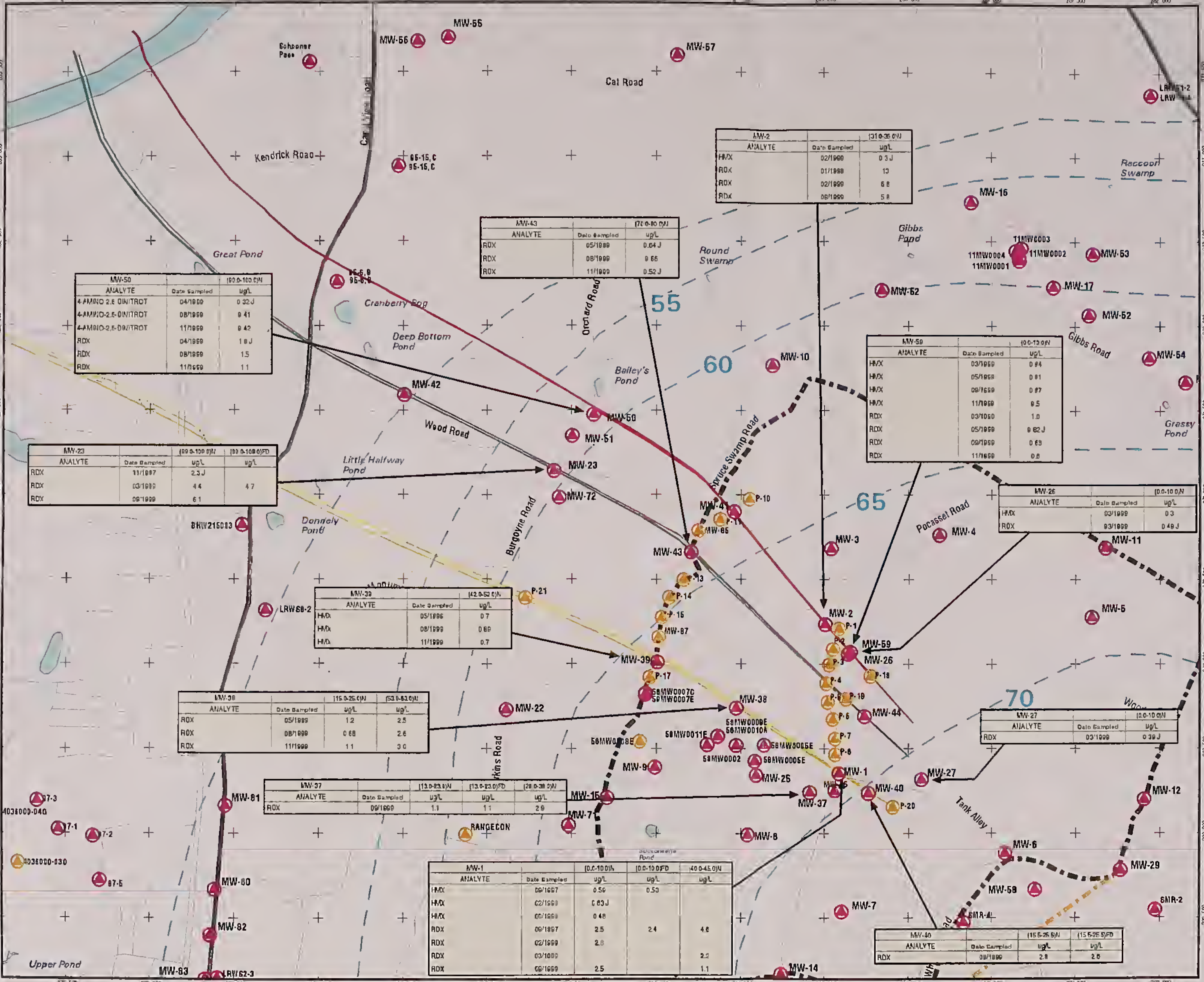

MW-2		(31.0-36.0)N
ANALYTE	Date Sampled	ug/L
HMX	02/1999	0.3 J
RDX	01/1998	13
RDX	02/1999	6.8
RDX	08/1999	5.8

MW-43		(70.0-80.0)N
ANALYTE	Date Sampled	ug/L
RDX	05/1999	0.64 J
RDX	08/1999	0.66
RDX	11/1999	0.52 J

MW-50		(90.0-100.0)N
ANALYTE	Date Sampled	ug/L
4-AMINO-2,6-DINITROT	04/1999	0.32 J
4-AMINO-2,6-DINITROT	08/1999	0.41
4-AMINO-2,6-DINITROT	11/1999	0.42
RDX	04/1999	1.0 J
RDX	08/1999	1.5
RDX	11/1999	1.1

MW-23		(99.0-109.0)N	(99.0-109.0)FD
ANALYTE	Date Sampled	ug/L	ug/L
RDX	11/1997	2.3 J	
RDX	03/1999	4.4	4.7
RDX	09/1999	6.1	

MW-59		(0.0-13.0)N
ANALYTE	Date Sampled	ug/L
HMX	03/1999	0.64
HMX	05/1999	0.81
HMX	09/1999	0.87
HMX	11/1999	0.5
RDX	03/1999	1.0
RDX	05/1999	0.82 J
RDX	09/1999	0.63
RDX	11/1999	0.8

MW-26		(0.0-10.0)N
ANALYTE	Date Sampled	ug/L
HMX	03/1999	0.3
RDX	03/1999	0.49 J

MW-39		(42.0-52.0)N
ANALYTE	Date Sampled	ug/L
HMX	05/1998	0.7
HMX	08/1999	0.69
HMX	11/1999	0.7

MW-38		(15.0-25.0)N	(53.0-63.0)N
ANALYTE	Date Sampled	ug/L	ug/L
RDX	05/1999	1.2	2.5
RDX	08/1999	0.68	2.6
RDX	11/1999	1.1	3.0

MW-37		(13.0-23.0)N	(13.0-23.0)FD	(28.0-38.0)N
ANALYTE	Date Sampled	ug/L	ug/L	ug/L
RDX	09/1999	1.1	1.1	2.9

MW-1		(0.0-10.0)N	(0.0-10.0)FD	(40.0-45.0)N
ANALYTE	Date Sampled	ug/L	ug/L	ug/L
HMX	09/1997	0.59	0.53	
HMX	02/1999	0.63 J		
HMX	08/1999	0.48		
RDX	09/1997	2.5	2.4	4.6
RDX	02/1999	2.8		
RDX	03/1999			2.2
RDX	08/1999	2.5		1.1

MW-27		(0.0-10.0)N
ANALYTE	Date Sampled	ug/L
RDX	03/1999	0.39 J

MW-40		(15.5-25.5)N	(15.5-25.5)FD
ANALYTE	Date Sampled	ug/L	ug/L
RDX	09/1999	2.8	2.6

MMR Groundwater Study

LEGEND

● Groundwater Wells

● Proposed Well Locations

ug/L	Micrograms Per Liter
J	Estimated Quantity
FD	Field Duplicate
N	Normal Environmental Sample

NOTE: Profile and monitoring well results from ongoing installation of proposed wells are not reported.

All sample depth measurements are in feet below watertable

BASEMAP LEGEND

- Group 1 Particle Tracks
- Group 2 Particle Tracks
- Group 3 Particle Tracks
- Groundwater Contours
- MMR Boundary
- Impact Area Boundary
- Former Impact Area Boundary
- Roads

LOCATION MAP

NOTES & SOURCES

Chemical database last queried on Mar 16 12:34

Map coordinates: Stateplane, NAD83, Zone 4151, Meters

TITLE

Detected Explosive Compounds in Groundwater
Central Impact Area
Feasibility Study Work Plan

FIGURE

2-3

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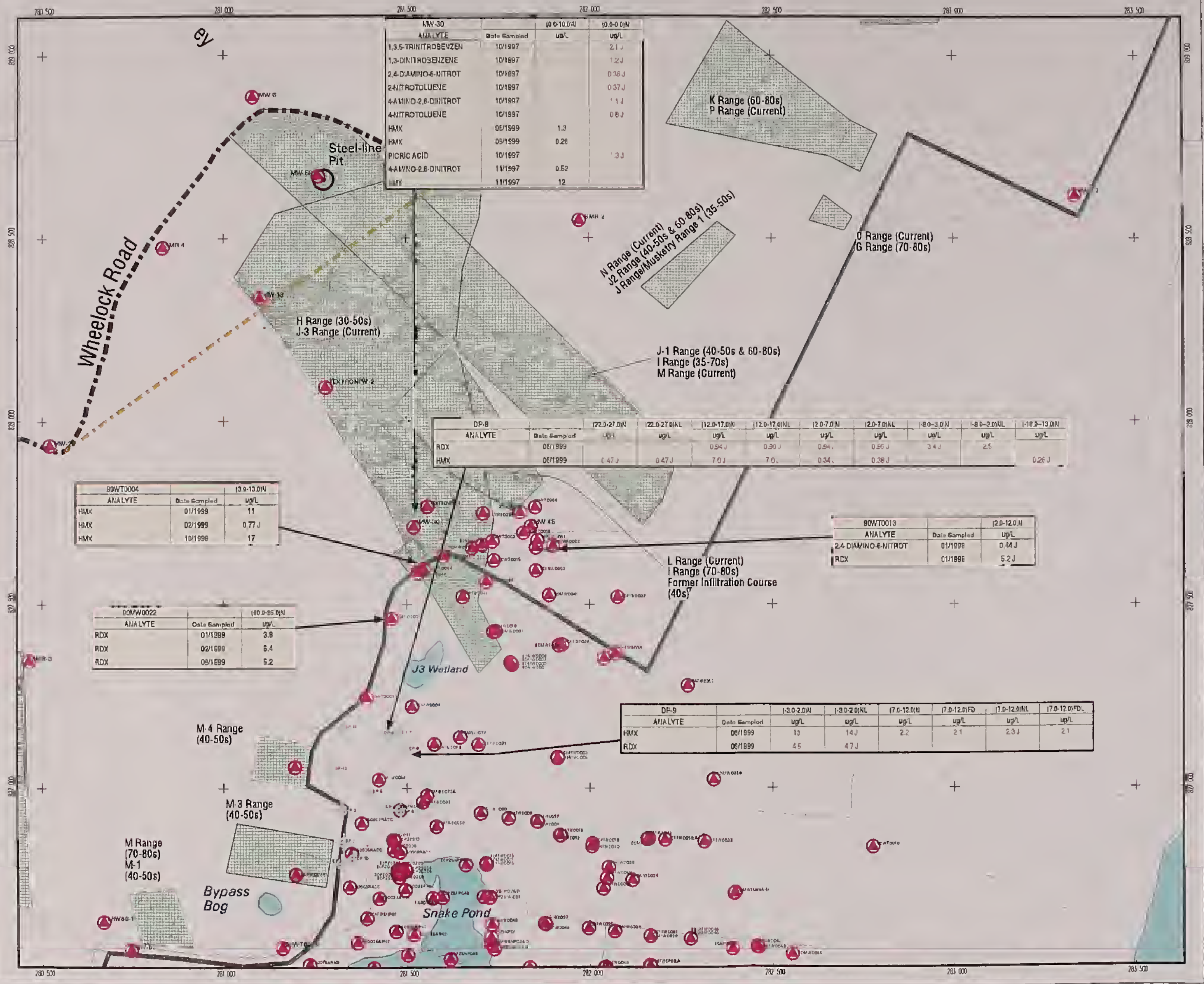

MW-30		(0.0-10.0)N	(0.0-0.0)N
ANALYTE	Date Sampled	ug/L	ug/L
1,3,5-TRINITROBENZEN	10/1997		2.1 J
1,3-DINITROBENZENE	10/1997		1.2 J
2,4-DIAMINO-6-NITROT	10/1997		0.36 J
2-NITROTOLUENE	10/1997		0.37 J
4-AMINO-2,6-DINITROT	10/1997		1.1 J
4-NITROTOLUENE	10/1997		0.8 J
HMX	05/1999	1.3	
HMX	09/1999	0.26	
PICRIC ACID	10/1997		1.3 J
4-AMINO-2,6-DINITROT	11/1997	0.52	
HMX	11/1997	12	

DP-8		(22.0-27.0)N	(22.0-27.0)NL	(12.0-17.0)N	(12.0-17.0)NL	(2.0-7.0)N	(2.0-7.0)NL	(-8.0-3.0)N	(-8.0-3.0)NL	(-18.0-13.0)N
ANALYTE	Date Sampled	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
RDX	06/1999			0.94 J	0.90 J	0.94 J	0.96 J	3.4 J	2.5	
HMX	06/1999	0.47 J	0.47 J	7.0 J	7.0 J	0.34 J	0.38 J			0.26 J

90WT0004		(3.0-13.0)N
ANALYTE	Date Sampled	ug/L
HMX	01/1999	11
HMX	02/1999	0.77 J
HMX	10/1998	17

90WT0013		(2.0-12.0)N
ANALYTE	Date Sampled	ug/L
2,4-DIAMINO-6-NITROT	01/1998	0.44 J
RDX	01/1998	5.2 J

90MW0022		(80.0-85.0)N
ANALYTE	Date Sampled	ug/L
RDX	01/1999	3.8
RDX	02/1999	6.4
RDX	09/1999	5.2

DP-9		(-3.0-2.0)N	(-3.0-2.0)NL	(7.0-12.0)N	(7.0-12.0)FD	(7.0-12.0)NL	(7.0-12.0)FDL
ANALYTE	Date Sampled	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
HMX	06/1999	13	14 J	2.2	2.1	2.3 J	2.1
RDX	06/1999	4.5	4.7 J				

MMR
Groundwater Study

LEGEND

●	Groundwater Wells
	Drive Points
ug/L	Micrograms Per Liter
J	Estimated Quantity
FD	Field Duplicate
N	Normal Environmental Sample
NL	Normal Filtered Sample
FDL	Field Duplicate Filtered Sample

Concentrations from Profile Samples

All sample depth measurements are in feet below watertable

BASEMAP LEGEND

MMR Boundary
Impact Area Boundary
Former Impact Area Boundary
Roads
Ranges
Steel-lined Pit

LOCATION MAP

NOTES & SOURCES

Chemical database last queried on. Mar 16 12 34

Map coordinates: Stateplane, NAD83, Zone 4151, Meters

TITLE

Detected Explosive Compounds in Groundwater
Southeast Corner of the Ranges
Feasibility Study Work Plan

N

0 800
FEET
0 274
METERS

FIGURE
2-4

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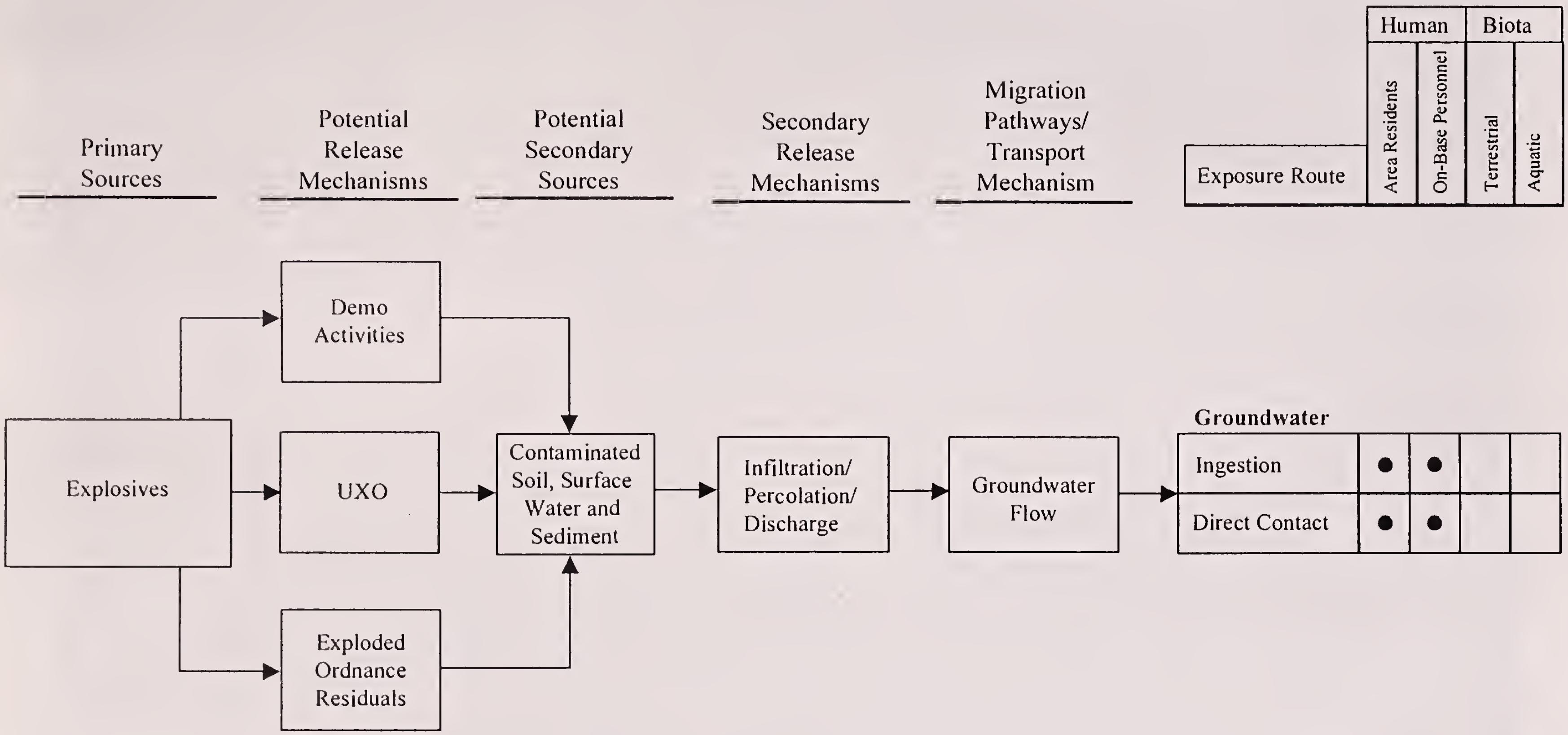
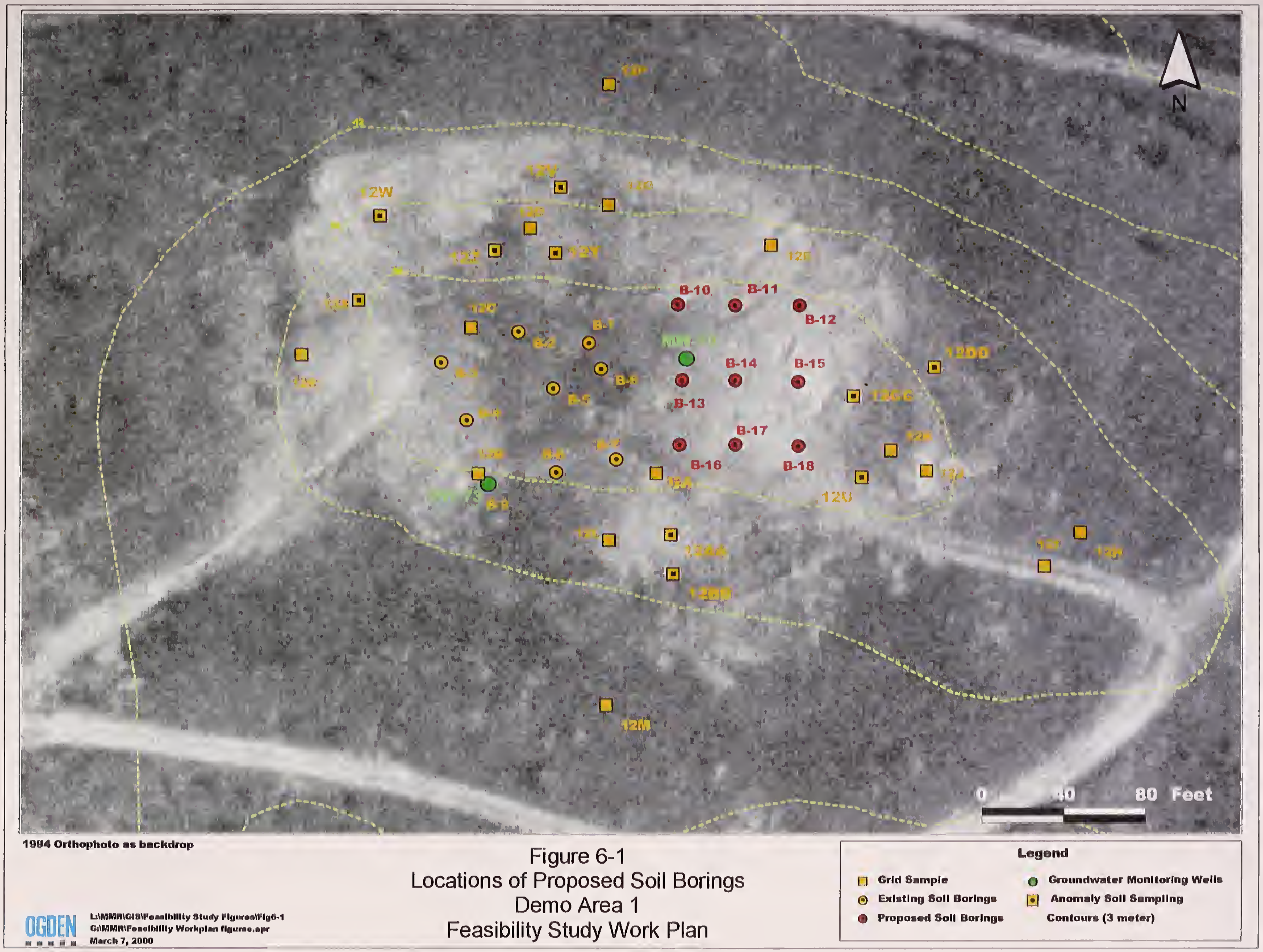
Figure 3-1
Preliminary Conceptual Site Model
Feasibility Study Work Plan


Primary Sources
Potential Release Mechanisms
Potential Secondary Sources
Secondary Release Mechanisms
Migration Pathways/ Transport Mechanism
Exposure Route
Human
Biota
Area Residents
On-Base Personnel
Terrestrial
Aquatic
Explosives
Demo Activities
UXO
Exploded Ordnance Residuals
Contaminated Soil, Surface Water and Sediment
Infiltration/ Percolation/ Discharge
Groundwater Flow
Groundwater
Ingestion
Direct Contact
●
●
●
●



1994 Orthophoto as backdrop

Figure 6-1
Locations of Proposed Soil Borings
Demo Area 1
Feasibility Study Work Plan

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G:\MMR\Feasibility Workplan figures.apr
March 7, 2000

Site Characterization (AO1)

Demo Area 1

Activity ID	Activity Description	ENF MILE	REM DUR	Start	Finish
00110	Demo 1 Soil/GW Investigation		17	14OCT99A	23MAR00
00120	Demo 1 Soil/GW Report Preparation		65	09MAR00	08JUN00
00130	Demo 1 Draft Soil/GW Report	YES	0		08JUN00
00140	Demo 1 Revise Draft Report		80	09JUN00	02OCT00
00150	Demo 1 Final Soil/GW Report	YES	0		02OCT00
00160	Demo 1 Geophysics Investigation		76	05JAN00A	15JUN00
00170	Demo 1 Geophysics Presentation		0		15JUN00
00175	Start Soil Investigation	YES	0	05JUL00	
00180	Soil Investigation		50	05JUL00	13SEP00
00185	Soil Investig. Report Preparation		60	14SEP00	08DEC00
00190	Draft Soil Report	YES	0		08DEC00
00195	Revise Draft Soil Report		60	11DEC00	07MAR01
00200	Final Soil Report		0		07MAR01

Fate and Transport Modeling

Activity ID	Activity Description	ENF MILE	REM DUR	Start	Finish
07100	Modeling Planning		0	01JAN99A	22JUL99A
07110	Draft Modeling Proposal		0		22JUL99A
07120	Revise Modeling Proposal		8	23JUL99A	10MAR00
07130	Develop Model Parameters		147	13MAR00	06OCT00
07140	Modeling to Develop Soil Cleanup		44	09OCT00	11DEC00

Feasibility Studies (AO3)

FS Workplan

Activity ID	Activity Description	ENF MILE	REM DUR	Start	Finish
20110	FS Workplan Preparation		28	14FEB00A	07APR00
20120	FS Draft Workplan	YES	0		07APR00
20130	FS Revise Draft Workplan		60	10APR00	03JUL00
20140	FS Final Workplan		0		03JUL00

Demo Area 1

Soil Operable Unit

Activity ID	Activity Description	ENF MILE	REM DUR	Start	Finish
21170	FS Screening Report Preparation		133	05JUL00	12JAN01
21180	Draft FS Screening Report	YES	0		12JAN01
21190	Revise Draft FS Screening Report		60	15JAN01	09APR01
21200	Final FS Screening Report		0		09APR01
21210	Post-Screening Invest. Workplan Prep.		22	10APR01	09MAY01
21220	Draft Post-Screening Invest. Workplan	YES	0		09MAY01
21230	Revise Draft PSI Workplan		60	10MAY01	03AUG01
21240	Final Post-Screening Workplan		0		03AUG01
21250	Start Post-Screening Investigation	YES	0	06AUG01	
21260	Post-Screening Investigation		80	06AUG01	26NOV01
21310	FS Preparation		40	27NOV01	25JAN02
21320	Draft FS	YES	0		25JAN02

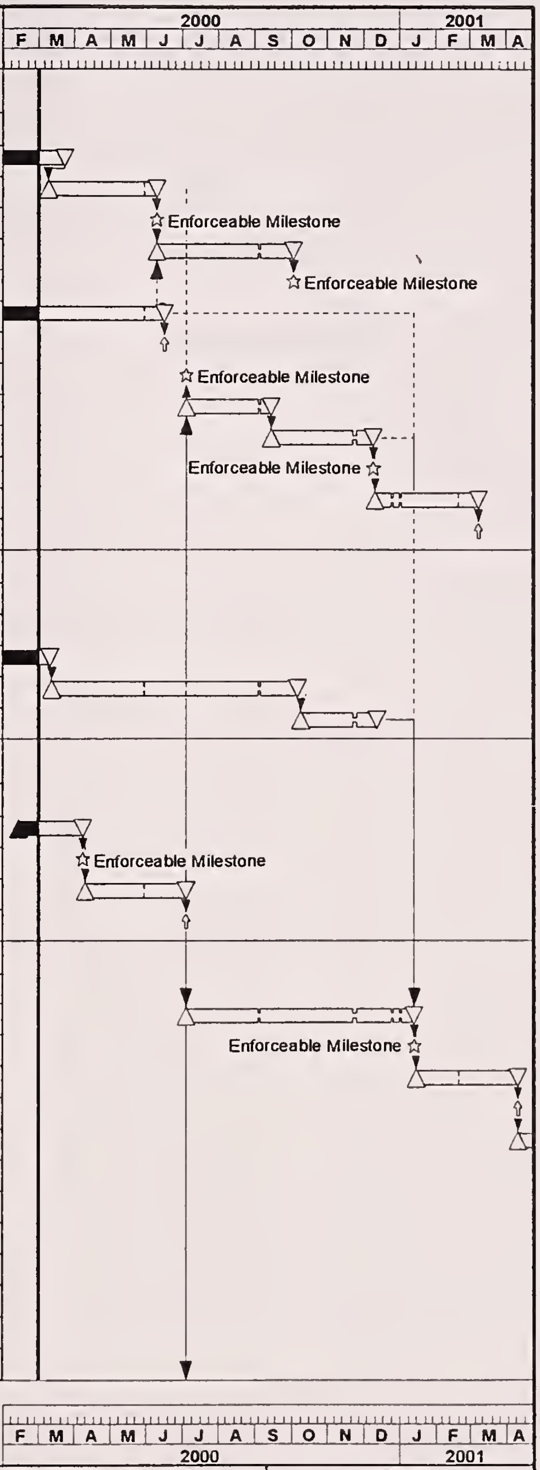

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Figure 8-1. Schedule for Site Characterization and FS for Demo 1 as of 3/1/00

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Date	Revision	Checked	Approved

Activity ID	Activity Description	ENF MILE	REM DUR	Start	Finish
Soil Operable Unit					
21330	Revise Draft FS		60	28JAN02	19APR02
21340	Final FS		0		19APR02
Groundwater Operable Unit					
21510	FS Screening Report Preparation		22	05JUL00	03AUG00
21520	Draft FS Screening Report	YES	0		03AUG00
21530	Revise Draft FS Screening Report		60	04AUG00	27OCT00
21540	Final FS Screening Report		0		27OCT00
21550	Post-Screening Invest. Workplan Prep.		22	30OCT00	30NOV00
21560	Draft Post-Screening Invest. Workplan	YES	0		30NOV00
21570	Revise Draft PSI Workplan		60	01DEC00	27FEB01
21580	Final Post-Screening Workplan		0		27FEB01
21590	Start Post-Screening Investigation	YES	0	28FEB01	
21600	Post-Screening Investigation		80	28FEB01	20JUN01
21650	FS Preparation		40	21JUN01	16AUG01
21660	Draft FS	YES	0		16AUG01
21670	Revise Draft FS		60	17AUG01	09NOV01
21680	Final FS		0		09NOV01

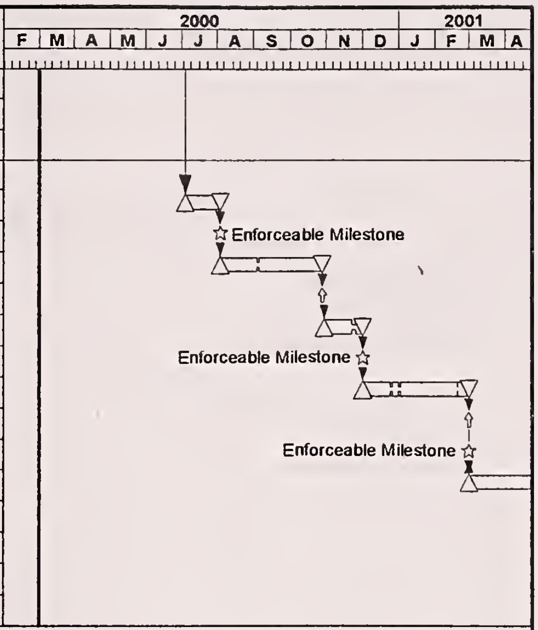

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Figure 8-1. Schedule for Site Characterization and FS for Demo 1 as of 3/1/00

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Date	Revision	Checked	Approved

Activity ID	Activity Description	ENF MILE	REM DUR	Start	Finish
Site Characterization (AO1)					
Central Impact Area					
00210	Impact Area Planning		0	23AUG99A	24JAN00A
00220	Impact Area Start Data Collection	YES	0	05JAN00A	
00230	Impact Area Investigation		105	05JAN00A	27JUL00
00240	Impact Area Report Preparation		65	13JUL00	12OCT00
00250	Impact Area Draft Report	YES	0		12OCT00
00260	Impact Area Revise Draft Report		83	13OCT00	12FEB01
00270	Impact Area Final Report	YES	0		12FEB01
00272	Response Plan Preparation		60	03MAY00	27JUL00
00274	Response Plan Investigation		105	13JUL00	11DEC00
00276	Response Plan Report Prep.		65	27NOV00	28FEB01
00278	Response Plan Draft Report	YES	0		28FEB01
00280	Response Plan Revise Draft Report		83	01MAR01	26JUN01
00282	Response Plan Final Report		0		26JUN01
High Use Target Area 1					
01110	HUTA Planning		13	10JAN00A	17MAR00
01120	HUTA Draft Workplan		0		17MAR00
01130	HUTA Revise Draft Workplan		20	20MAR00	14APR00
01140	HUTA Final Workplan		0		14APR00
01160	HUTA Investigation		188	10APR00	05JAN01
01170	HUTA Report Preparation		47	15DEC00	22FEB01
01180	HUTA Draft Report	YES	0		22FEB01
01190	HUTA Revise Draft Report		63	23FEB01	22MAY01
01195	HUTA Final Report		0		22MAY01
Fate and Transport Modeling					
07100	Modeling Planning		0	01JAN99A	22JUL99A
07110	Draft Modeling Proposal		0		22JUL99A
07120	Revise Modeling Proposal		8	23JUL99A	10MAR00
07130	Develop Model Parameters		147	13MAR00	06OCT00
07140	Modeling to Develop Soil Cleanup		44	09OCT00	11DEC00
Feasibility Studies (AO3)					
FS Workplan					
20110	FS Workplan Preparation		28	14FEB00A	07APR00
20120	FS Draft Workplan	YES	0		07APR00
20130	FS Revise Draft Workplan		60	10APR00	03JUL00
20140	FS Final Workplan		0		03JUL00
Central Impact Area					
22110	FS Screening Report Preparation		183	11JUL00	30MAR01
22120	Draft FS Screening Report	YES	0		30MAR01
22130	Revise Draft FS Screening Report		60	02APR01	25JUN01

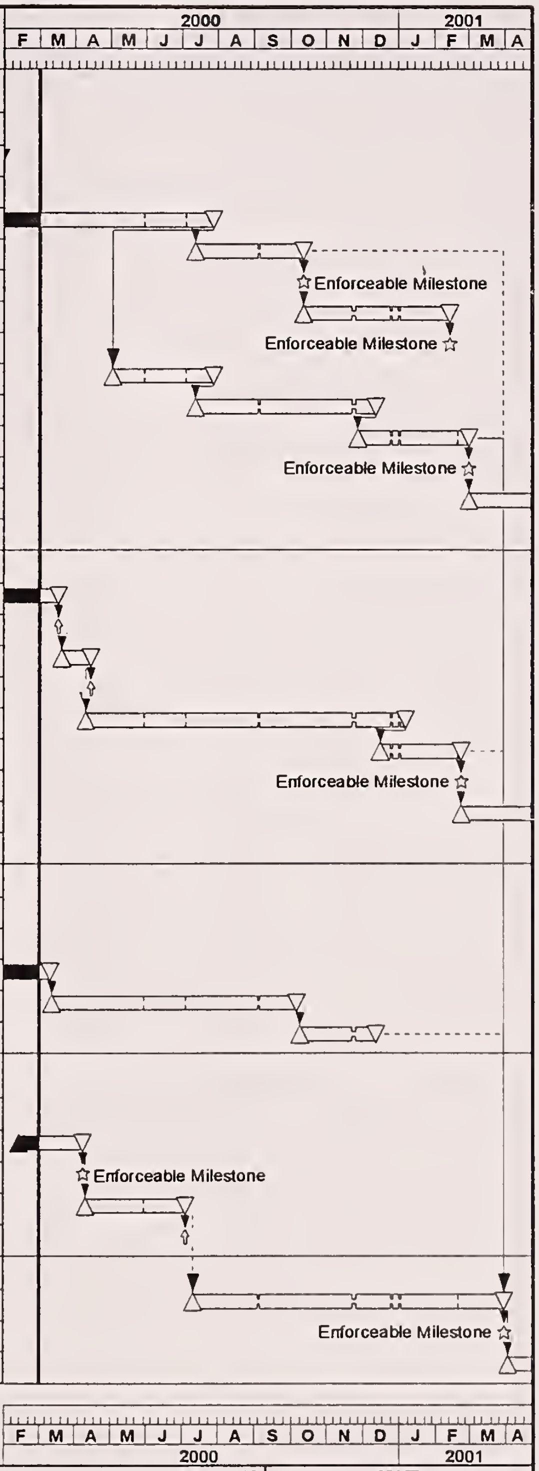

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Figure 8-2. Schedule for Site Characterization and FS for Central Impact Area as of 3/1/00

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Date	Revision	Checked	Approved

Activity ID	Activity Description	ENF MILE	REM DUR	Start	Finish
Central Impact Area					
22140	Final FS Screening Report		0		25JUN01
22150	Post-Screening Invest. Workplan Prep.		22	26JUN01	26JUL01
22160	Draft Post-Screening Invest. Workplan	YES	0		26JUL01
22170	Revise Draft PSI Workplan		60	27JUL01	19OCT01
22180	Final Post-Screening Workplan		0		19OCT01
22190	Start Post-Screening Investigation	YES	0	22OCT01	
22200	Post-Screening Investigation		80	22OCT01	14FEB02
22210	FS Preparation		40	15FEB02	11APR02
22220	Draft FS	YES	0		11APR02
22230	Revise Draft FS		60	12APR02	04JUL02
22240	Final FS		0		04JUL02

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Figure 8-2. Schedule for Site Characterization and FS for Central Impact Area as of 3/1/00

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Date	Revision	Checked	Approved

Site Characterization (AO1)

J-2 Range

Activity ID	Activity Description	ENF MILE	REM DUR	Start	Finish
00310	J-2 Range Planning		28	08FEB00A	07APR00
00320	J-2 Range Draft Workplan	YES	0		07APR00
00330	J-2 Range Rev. Draft Workplan		80	10APR00	01AUG00
00340	J-2 Range Final Workplan		0		01AUG00
00350	J-2 Range Start Data Collection	YES	0	05JUL00	
00360	J-2 Range Investigation		88	05JUL00	06NOV00
00365	J-2 Range Geophysics Investigation		87	15MAY00*	15SEP00
00367	J-2 Range Geophysics Presentation		0		13OCT00*
00370	J-2 Range Report Preparation		62	23OCT00	22JAN01
00380	J-2 Range Draft Report	YES	0		22JAN01
00390	J-2 Range Revise Draft Report		82	23JAN01	17MAY01
00391	J-2 Range Final Report	YES	0		17MAY01
00392	Additional Delineation Planning		60	06OCT00	03JAN01
00393	Additional Delineation Investigation		80	18DEC00	11APR01
00394	Additional Delineation Report Prep.		65	28MAR01	27JUN01
00395	Additional Delineation Draft Report	YES	0		27JUN01
00396	Additional Delineation Rev. Draft Report		83	28JUN01	24OCT01
00397	Additional Delineation Final Report		0		24OCT01

J-1/J-3 Range

Activity ID	Activity Description	ENF MILE	REM DUR	Start	Finish
00400	Prepare Response Plan for RDX		0	01DEC99A	16FEB00A
00401	Draft Response Plan for RDX		0		16FEB00A
00402	Revise Response Plan for RDX		23	17FEB00A	31MAR00
00403	Final Response Plan for RDX		0		31MAR00
00404	Implement Response Plan for RDX		44	03APR00	02JUN00
00405	Review RP Results & Plan Follow-up		22	05JUN00	05JUL00
00410	J-1/J-3 Range Planning		38	06DEC99A	21APR00
00420	J-1/J-3 Range Draft Workplan	YES	0		21APR00
00430	J-1/J-3 Range Rev. Draft Workplan		83	24APR00	18AUG00
00440	J-1/J-3 Range Final Workplan		0		18AUG00
00450	J-1/J-3 Range Start Data Cllctn	YES	0	26JUL00	
00460	J-1/J-3 Range Investigation		88	26JUL00	29NOV00
00465	J-1/J-3 Range Geophys. Investigation		87	15MAY00*	15SEP00
00467	J-1/J-3 Range Geophys. Presentation		0		13OCT00*
00470	J-1/J-3 Range Report Preparation		62	13NOV00	12FEB01
00480	J-1/J-3 Range Draft Report	YES	0		12FEB01
00490	J-1/J-3 Range Rev. Draft Report		81	13FEB01	07JUN01
00491	J-1/J-3 Range Final Report	YES	0		07JUN01
00492	Additional Delineation Planning		60	27OCT00	24JAN01
00493	Additional Delineation Investigation		88	10JAN01	14MAY01
00494	Additional Delineation Report Prep.		65	18APR01	19JUL01

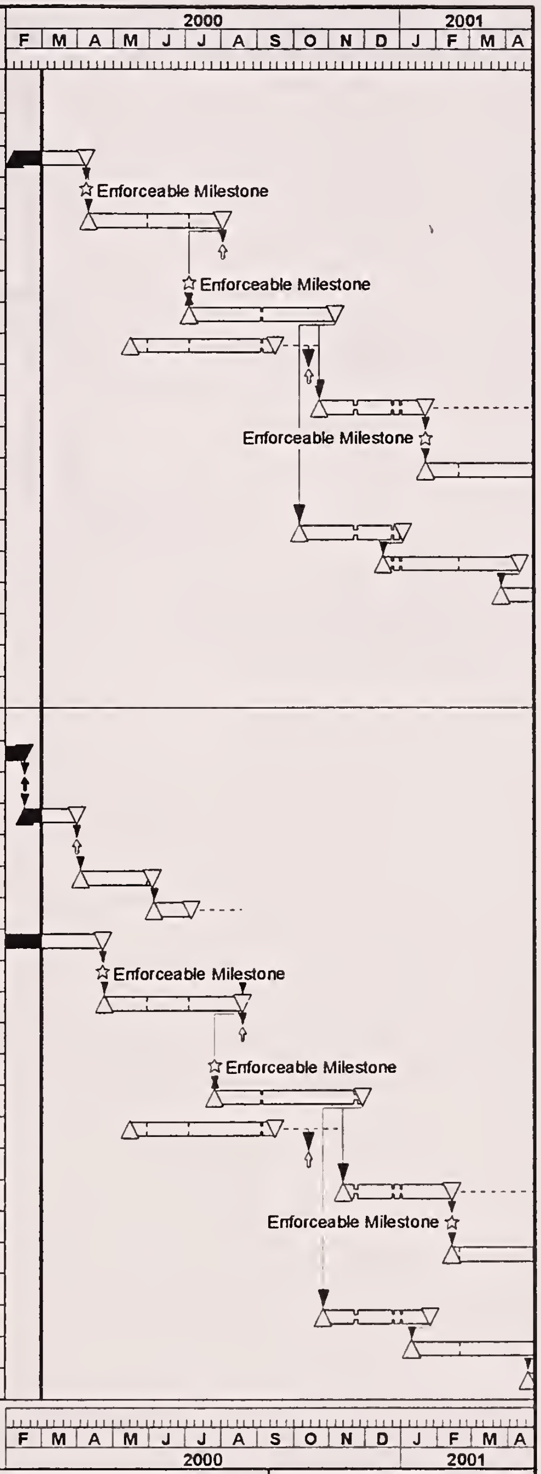

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Figure 8-3. Schedule for Site Characterization and FS for SE Corner of Ranges as of 3/1/00

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Date	Revision	Checked	Approved

Activity ID	Activity Description	ENF MILE	REM DUR	Start	Finish
J-1/J-3 Range					
00495	Additional Delineation Draft Report	YES	0		19JUL01
00496	Additional Delineation Rev. Draft Report		83	20JUL01	14NOV01
00497	Additional Delineation Final Report		0		14NOV01
Fate and Transport Modeling					
07100	Modeling Planning		0	01JAN99A	22JUL99A
07110	Draft Modeling Proposal		0		22JUL99A
07120	Revise Modeling Proposal		8	23JUL99A	10MAR00
07130	Develop Model Parameters		147	13MAR00	06OCT00
07140	Modeling to Develop Soil Cleanup		44	09OCT00	11DEC00
Feasibility Studies (AO3)					
FS Workplan					
20110	FS Workplan Preparation		28	14FEB00A	07APR00
20120	FS Draft Workplan	YES	0		07APR00
20130	FS Revise Draft Workplan		60	10APR00	03JUL00
20140	FS Final Workplan		0		03JUL00
SE Corner of Ranges					
23110	FS Screening Report Preparation		271	26JUL00	20AUG01
23120	Draft FS Screening Report	YES	0		20AUG01
23130	Revise Draft FS Screening Report		60	21AUG01	13NOV01
23140	Final FS Screening Report		0		13NOV01
23150	Post-Screening Invest. Workplan Prep.		22	14NOV01	17DEC01
23160	Draft Post-Screening Invest. Workplan	YES	0		17DEC01
23170	Revise Draft PSI Workplan		60	18DEC01	13MAR02
23180	Final Post-Screening Workplan		0		13MAR02
23190	Start Post-Screening Investigation	YES	0	14MAR02	
23200	Post-Screening Investigation		80	14MAR02	03JUL02
23210	FS Preparation		40	04JUL02	28AUG02
23220	Draft FS	YES	0		28AUG02
23230	Revise Draft FS		60	29AUG02	20NOV02
23240	Final FS		0		20NOV02

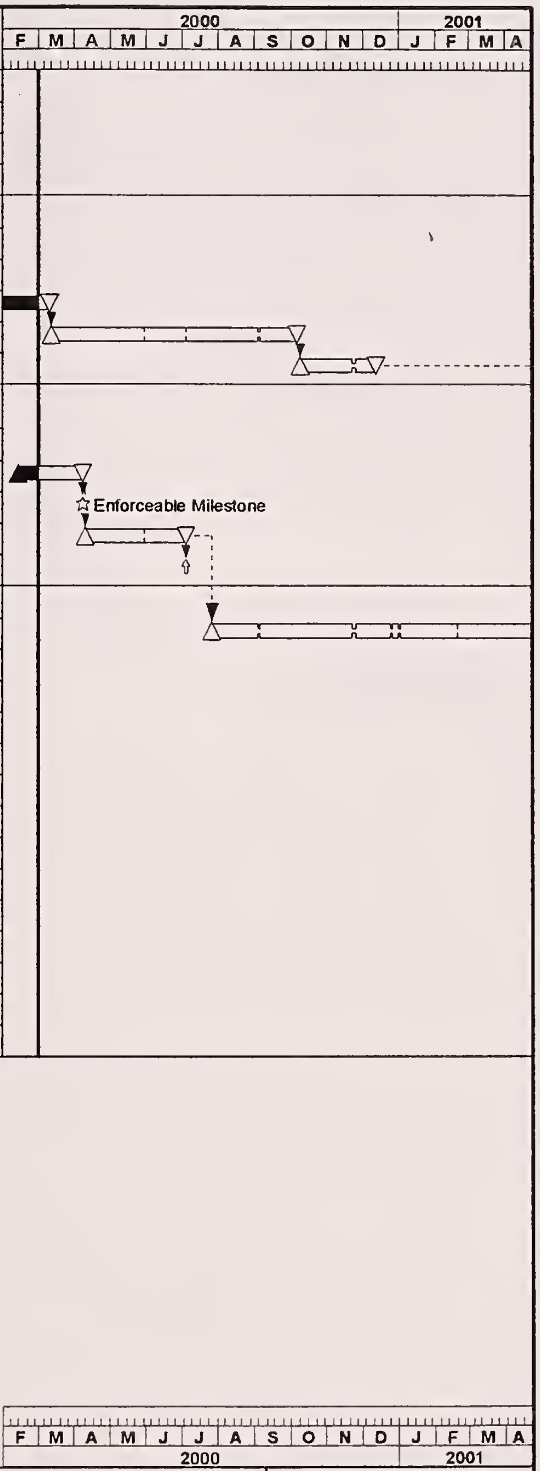

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Figure 8-3. Schedule for Site Characterization and FS for SE Corner of Ranges as of 3/1/00

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Date	Revision	Checked	Approved

Activity ID	Activity Description	ENF MILE	REM DUR	Start	Finish
Site Characterization (AO1)					
Demo Area 1					
00160	Demo 1 Geophysics Investigation		76	05JAN00A	15JUN00
00170	Demo 1 Geophysics Presentation		0		15JUN00
J-2 Range					
00365	J-2 Range Geophysics Investigation		87	15MAY00*	15SEP00
00367	J-2 Range Geophysics Presentation		0		13OCT00*
J-1/J-3 Range					
00465	J-1/J-3 Range Geophys. Investigation		87	15MAY00*	15SEP00
00467	J-1/J-3 Range Geophys. Presentation		0		13OCT00*
Gun/Mortar Positions					
00515	Gun/Mortar Geophys. Presentation		0		12APR00*
High Use Target Area 1					
01110	HUTA Planning		13	10JAN00A	17MAR00
01120	HUTA Draft Workplan		0		17MAR00
01130	HUTA Revise Draft Workplan		20	20MAR00	14APR00
01140	HUTA Final Workplan		0		14APR00
01160	HUTA Investigation		188	10APR00	05JAN01
01170	HUTA Report Preparation		47	15DEC00	22FEB01
01180	HUTA Draft Report	YES	0		22FEB01
01190	HUTA Revise Draft Report		63	23FEB01	22MAY01
01195	HUTA Final Report		0		22MAY01
Water Bodies					
01210	Water Body Geophys. Investig.		76	19NOV99A	15JUN00
01220	Water Body Geophys. Present.		0		13JUL00*
Slit Trench					
01310	Slit Trench Geophys. Investig.		33	01MAY00*	15JUN00
01320	Slit Trench Geophys. Present.		0		13JUL00*
Fate and Transport Modeling					
07100	Modeling Planning		0	01JAN99A	22JUL99A
07110	Draft Modeling Proposal		0		22JUL99A
07120	Revise Modeling Proposal		8	23JUL99A	10MAR00
07130	Develop Model Parameters		147	13MAR00	06OCT00
07140	Modeling to Develop Soil Cleanup		44	09OCT00	11DEC00
Feasibility Studies (AO3)					
FS Workplan					
20110	FS Workplan Preparation		28	14FEB00A	07APR00
20120	FS Draft Workplan	YES	0		07APR00
20130	FS Revise Draft Workplan		60	10APR00	03JUL00
20140	FS Final Workplan		0		03JUL00

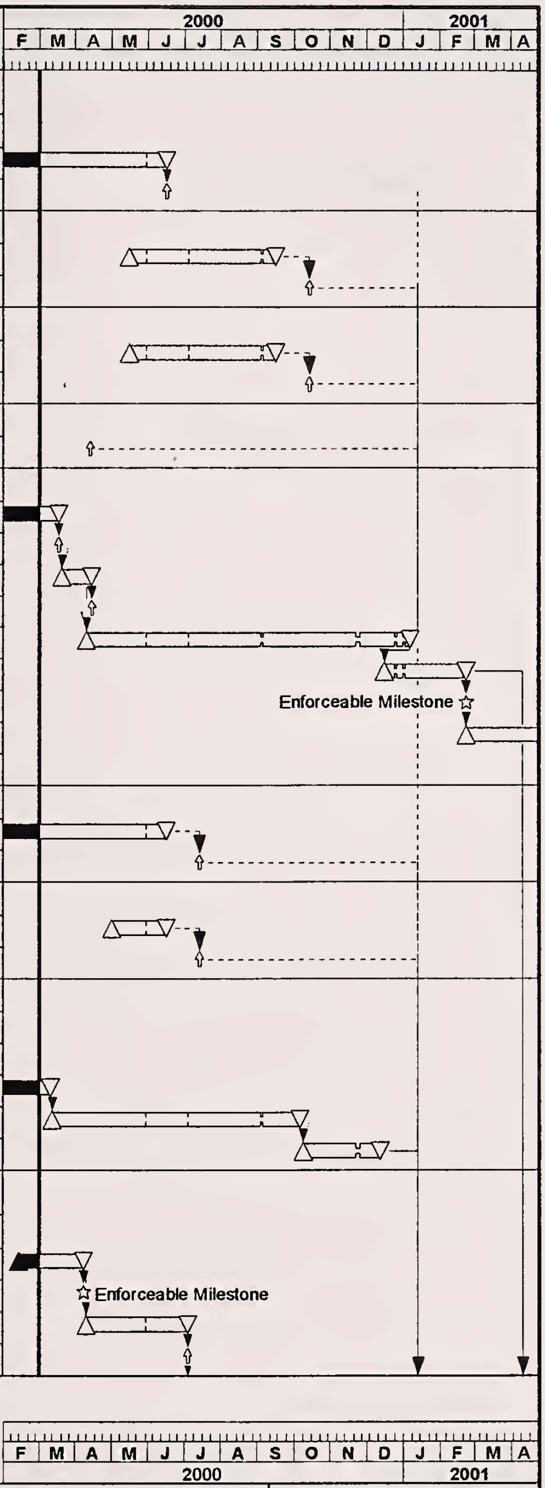

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Figure 8-4. Schedule for Site Characterization and FS for UXO as of 3/1/00

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Date	Revision	Checked	Approved

Activity ID	Activity Description	ENF MILE	REM DUR	Start	Finish
UXO					
HUTA1 Operable Unit					
24110	FS Screening Report Preparation		133	05JUL00	12JAN01
24120	Draft FS Screening Report	YES	0		12JAN01
24130	Revise Draft FS Screening Report		60	15JAN01	09APR01
24140	Final FS Screening Report		0		09APR01
24150	FS Preparation		40	13FEB01	10APR01
24160	Draft FS	YES	0		10APR01
24170	Revise Draft FS		60	11APR01	05JUL01
24180	Final FS		0		05JUL01
Other Operable Units					
24210	FS Screening Report Preparation		133	05JUL00	12JAN01
24220	Draft FS Screening Report	YES	0		12JAN01
24230	Revise Draft FS Screening Report		60	15JAN01	09APR01
24240	Final FS Screening Report		0		09APR01
24250	Post-Screening Invest. Workplan Prep.		22	10APR01	09MAY01
24260	Draft Post-Screening Invest. Workplan	YES	0		09MAY01
24270	Revise Draft PSI Workplan		60	10MAY01	03AUG01
24280	Final Post-Screening Workplan		0		03AUG01
24290	Start Post-Screening Investigation	YES	0	06AUG01	
24300	Post-Screening Investigation		80	06AUG01	26NOV01
24310	FS Preparation		40	27NOV01	25JAN02
24320	Draft FS	YES	0		25JAN02
24330	Revise Draft FS		60	28JAN02	19APR02
24340	Final FS		0		19APR02

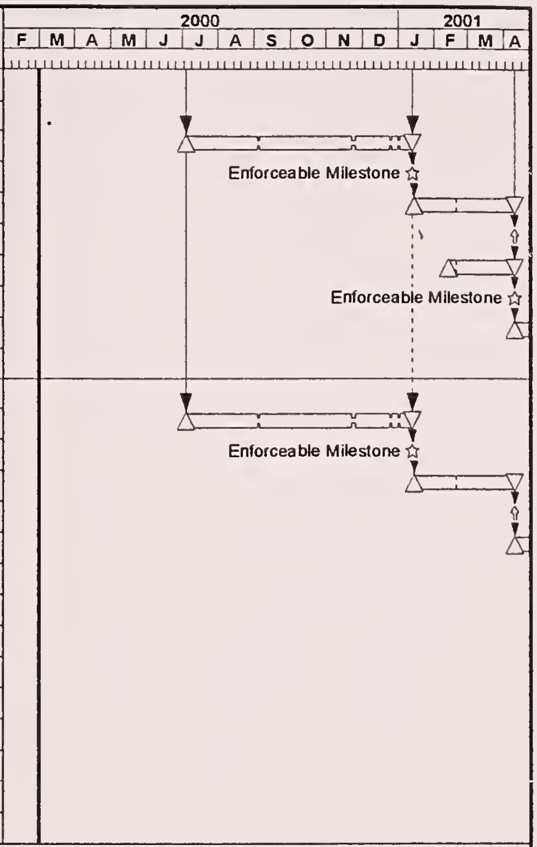

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Figure 8-4. Schedule for Site Characterization and FS for UXO as of 3/1/00

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Date	Revision	Checked	Approved

Tables

Table 1-1

Identification of Groundwater COPCs and PRGs
Feasibility Study Work Plan

Area of Concern	Groundwater COPCs (1)	Maximum Detected Concentration (2) (ug/L)	Groundwater Standards					Proposed Groundwater PRG (ug/L)
			EPA MCL (ug/L)	EPA SMCL (ug/L)	MCP GW-1 (ug/L)	EPA Lifetime HA (ug/L)	DWEL (ug/L)	
Demolition Area 1	RDX	370	NA	NA	NA	2	100	**2**
	2,4,6-TNT	16	NA	NA	NA	2	NA	**2**
Central Impact Area	RDX	13	NA	NA	NA	2	100	**2**
Southeast Corner of the Ranges	RDX	5.4	NA	NA	NA	2	100	**2**
	HMX	12	NA	NA	NA	400	2000	**400**

(1) Current COPCs based on EPA identification in AO#3 and existing contaminant concentrations COPCs will be modified based on results of additional investigations.

(2) Maximum concentration detected prior to January 1, 2000.

No COPCs have been identified for UXO. COPCs will be identified based on site characterization and fate and transport modeling.

COPCs and PRGs will continue to be updated as new data is generated from ongoing and planned Impact Area Groundwater Investigations.

COPC = Contaminant of Potential Concern
PRG = Preliminary Remediation Goal
HA = Health Advisory
NA = Not available

TABLE 2-1
Typical Explosive, Propellant, and Pyrotechnic Compounds

Constituents of Munitions	Phase I Analyte	Method(a)	Mobility(b)	Comments(c)
Explosives - Parent/Specific Child Constutuents				
1,3,5-Trinitrobenzene (TNB)	Y	8330	0.35g/l water	Resistant to photodegradation, persistent in soils [16]
3,5-Dinitroaniline	Y(as TIC)	SVOC TIC	sl sol. solid	Biodegradation product
2,4,6-Trinitrotoluene (TNT)	Y	8330		
4-Amino-2,6-dinitro-N-methylaniline	N			Possible TNT biodegradation product [22,29]
Aryl amines	Y(as TIC)	SVOC TICs		Representative compounds on SVOC TAL (e g aniline)
2,2',6,6'-Tetranitro-4,4'-azoxytoluene	N		insol; solid	TNT biodegradation intermediate[6,7,12,18,29]
2,4,6-Triaminotoluene	N			TNT biodegradation intermediate, persists <2 hrs [8,28]
2,4',6,6'-Tetranitro-2,4'-azoxytoluene	N		insol; solid	TNT biodegradation intermediate[14,29,30]
2-Hydroxylamino-4,6-dinitrotoluene	N			TNT biodegradation intermediate [8,16,29]
4,2',6,6'-Tetranitro-2,4'-azoxytoluene	N		insol; solid	TNT biodegradation intermediate [7,21,22,29,30]
4,4',6,6'-Tetranitro-2,2'-azoxytoluene	N		insol; solid	TNT biodegradation intermediate [6,7,12,18,29,30]
4-Hydroxylamino-2,6-dinitrotoluene	N			TNT biodegradation intermediate [8,16,29]
4-Amino-2,6-dinitrotoluene (4A-2,6-DNT)	Y	8330		TNT biodegradation product, major product, persistent in soils[21,27,28]
2-Amino-4,6-dinitrotoluene (2A-4,6-DNT)	Y	8330		TNT biodegradation product, major product, persistent in soils[21,28]
2,4-Diamino-6-nitrotoluene(2,4-DANT)	Y	8330		TNT biodegradation product, major product, persistent in soils[8,14]
2,6-Diamino-4-nitrotoluene (2,6-DANT)	Y	8330		TNT biodegradation product, major product, persistent in soils[8,14]
2,4,6-Trinitrobenzoic acid	N		sol 2.5%	TNT oxidation and photolysis intermediate[29]
2,3-Dinitrophenylamine	N		solid	TNT oxidation product, photodegrades [29]
2-Amino-4,6-dinitrobenzoic acid	N		sl.sol.	PossibleTNT photodegradation product,less stable that TNT[19,27,29]
1,3-Dinitrobenzene	Y	8330		Target analyte, possible TNT photolysis intermediate
2,4,6-Trinitrobenzylalcohol	N			Possible TNT photolysis intermediate no standard available[18,29]
3,5-Dinitrophenol	N			Possible TNT photolysis intermediate[5,7,13,17,29]
2,4-Dinitrobenzaldehyde	N			Possible TNT photolysis intermediate
2,4,6-Trinitroaniline (picramide)	N		sl sol.	Possible TNT photolysis product[22,29] no standard available
2,4,6-Trinitrobenzaldehyde	Y(as TIC)	SVOC TIC		Possible TNT photolysis product[10,18,29,30] no standard available
2,4,6-Trinitrobenzonitrile	N			Possible TNT photolysis product, unstable, forms condensation product[10,29,30]
3,5-Dinitroaniline	Y(as TIC)	SVOC TIC		Possible TNT photolysis product[22,23]
3,5-Dinitrocatechol	N			Possible TNT photolysis product[10] no standard available
3,5-Dinitrohydroquinone	N			Possible TNT photolysis product[10,29] no standard available
4,6-Dinitroanthanil(4,6-dinitro-1,2-benzisoxazole)	N			Possible TNT photolysis product(tentative identification)[2,11,18,29,30]
Oxalic acid amide	Y(as TIC)	SVOC TIC		Possible TNT photolysis product, degrades to oxalic acid and precipitates as calcium salt
TXD	N			Possible TNT photolysis product (tentative identification)[25,29]
TXDA	N			Possible TNT photolysis product (tentative identification)[25,29]
2,4-Dinitrotoluene (2,4-DNT)	Y	OC21B/8330		Persistent in soils[16]
2,4-Dinitrobenzaldehyde	N		sol.	Possible TNT photolysis intermediate, unstable[27,29]
4-Hydroxylamino-2-nitrotoluene	N			2,4-DNT biodegradation intermediate,unstable, peaks at 8 hrs [16]
4-Nitroso-2-nitrotoluene	N			Possible 2,4-DNT biodegradation intermediate [16]
2,2'-Dinitro-4,4-azoxytoluene	N		insol, solid	Possible2,4-DNT biodegradation intermediate[12,16]
2-Hydroxylamino-4-nitrotoluene	N			2,4-DNT biodegradation intermediate,unstable, peaks at 8 hrs [16]
2-Nitroso-4-nitrotoluene	N			Possible2,4-DNT biodegradation intermediate [2]
4,4'-Dinitro-2,2'-azoxytoluene	N		insol, solid	Possible2,4-DNT biodegradation intermediate
2-Amino-4-nitrotoluene	Y(as TIC)	SVOC TIC	sol. <1g/l	2,4-DNT biodegradation product[1,11,12,16]

TABLE 2-1
Typical Explosive, Propellant, and Pyrotechnic Compounds

Constituents of Munitions	Phase I Analyte	Method(a)	Mobility(b)	Comments(c)
Explosives - Parent/Specific Child Constituents (Cont.)				
Phloroglucinal(1,3,5-trihydroxybenzene)	Y(as TIC)			Possible 2,4-DNT biodegradation product
Phloroglucinal carboxylic acid	N			Possible 2,4-DNT biodegradation product, no standard available
Pyrogallol (1,2,3-trihydroxybenzene)	Y(as TIC)	SVOC TIC		Possible 2,4-DNT biodegradation product, no standard available, biodegrades
4-Acetamide-2-nitrotoluene	Y(as TIC)	SVOC TIC	sol	2,4 DNT biodegradation product[12] no standard available
4-Amino-2-nitrotoluene	N			2,4-DNT biodegradation product[1,11,12]
2-Amino-4-nitrobenzaldehyde	N			2,4-DNT photodegradation product, 10% yield [11] no standard available
2,2'-Carboxaldehyde-5,5'-dinitroazoxybenzene	N			2,4-DNT photodegradation product; 3% yield [11] no standard available
2,4-Dinitrobenzoic acid	N			2,4-DNT photodegradation product; 7% yield [11] no standard available
2-Amino-4-nitrobenzoic acid	N			2,4 DNT photodegradation product, 16% yield [11] no standard available
2,2'-Carboxy-5,5'-dinitroazoxybenzene	N			2,4-DNT photodegradation product, 10% yield [11] no standard available
2,6-Dinitrotoluene (2,6-DNT)	Y	8330		Persistent in soils [16]
2-Amino-6-nitrotoluene	Y(TIC)	SVOC TIC		2,6-DNT biodegradation product[1]
2,6-Dinitrobenzaldehyde	N			2,4-DNT photolysis intermediate
2- Nitrotoluene (NT)	Y	8330	insol	
3-Nitrotoluene (NT)	Y	8330	sol 0.495g/l	
4-Nitrotoluene (NT)	Y	8330	insol	
Pentaerythritol tetranitrate (PETN)	Y	8330	sol 0.0015g/l	
Pentaerythritol	N		sol.	Hydrolysis product, biodegradable
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	Y	8330		
Hydrazine	N		sol gas	Anaerobic biodegradation product, gas, 1/2life 5 hrs A, 7 days S, SW, 14 days GW[7,12,17]
1,1-Dimethylhydrazine	N		sol gas	Anaerobic biodegradation product, 1/2 life 8 hrs A, 22 days, S, SW, 44 days GW[7,12,17]
1,2-Dimethylhydrazine	N		sol gas	Anaerobic biodegradation product, 1/2 life 5 hrs A, 4 wks S, SW, 8 wks GW [7,12,17]
Dimethylnitrosamine(N-nitrosodimethylamine)	Y	OC21B		Target analyte, RDX biodegradation intermediate[17]
Methylene dinitramine	N			RDX biodegradation intermediate, does not persist
MNX (nitroso-dinitro-hexahydro-1,3,5-triazine)	N			Biodegradation intermediate, photolysis product, <0.6% of RDX conc [5,9,13,24]
N-hydroxy-methylene-hydrazone	N			RDX biodegradation intermediate[13,17]
N-hydroxy-methylethylene-dinitramine	N			RDX biodegradation intermediate [13,17]
Nitramide	N			RDX biodegradation intermediate [13,17]
DNX(dinitroso-nitro-hexahydro 1,3,5-triazine)	Y	SVOC TIC		RDX anaerobic biodegradation intermediate
Hydroxymethyl hydrazine	N			RDX anaerobic biodegradation intermediate[13,17]
1-Hydroxylamino-3,5-dinitro-1,3,5-triazine	N			RDX anaerobic biodegradation intermediate
1-Hydroxylamino-3,5-dinitroso-1,3,5-triazine	N			RDX anaerobic biodegradation intermediate
1-Hydroxylamino-3-nitroso-5-nitro-1,3,5-triazine	N			RDX anaerobic biodegradation intermediate
N-Hyroxylamino-N'-nitrosomethylene diamine	N			RDX anaerobic biodegradation product[13,17] standard unavailable
N-Nitroso-methylene diamine	N			RDX anaerobic biodegradation product[4] standard unavailable
TNX(Hexahydro-1,3,5-trinitroso-1,3,5-triazine)	N			Possible RDX anaerobic biodegradation product, ND in lab studies [26]
Nitrous oxide	N			Gas
Methanol	N		sol	RDX anaerobic biodegradation product, 1/2 life = 7 days S, SW, GW [17]

TABLE 2-1
Typical Explosive, Propellant, and Pyrotechnic Compounds

Constituents of Munitions	Phase I Analyte	Method[(a)]	Mobility[(b)]	Comments[(c)]
Explosives - Parent/Specific Child Constutuents (cont.)				
Ammonia	Y	350.2	sol	RDX photodegradation product, gas, ND if RDX<5ppb
Formamide	Y	SVOC TIC	sol.	Possible RDX photolysis product: 1/2 life 2 1 hrs A. ND if RDX<5ppb, biodegradable [4,24,25]
Methyl-2,4,6-trinitrophenolnitramine (Tetryl)	Y	8330		Phased out after WWII. 1/2 life=302 days
Methylnitramine	N			Tetryl photolysis product[9] standard not available
N-Nitroso-methylpicramide	N			Tetryl thermal and photolysis product [9,22] standard not available
Picramic acid(2-amino-4,6-dinitrophenol)	N		sol <1g/l	Tetryl thermal degradation product[20] , standard not available
Picramide(2,4,6-trinitroaniline)	N		insol	Tetryl thermal degradation product, standard not available
4-Nitroaniline	Y	OC21B	sol. <0.8g/l	Tetryl thermal degradation product, target analyte
2,4,6-Trinitroanisole	N			Tetryl thermal degradation product: standard not available
2,4,6-Trinitrophenol (picric acid, PA)	Y	8330		Hydrolysis product
Nitroglycerin (NG)	Y	8330		
Octahydro(1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX)	Y	8330		
Mono-nitroso-trinitro-1,3,5,7-tetrazoeine isomers	N			Possible HMX biodegradation intermediates
Di-nitroso-dinitro-1,3,5,7-tetrazoeine isomers	N			Possible HMX biodegradation intermediates
Tri-nitroso-nitro-1,3,5,7-tetrazocine isomers	N			Possible HMX biodegradation intermediates
1,3,5,7-tetranitroso-1,3,5,7-tetrazocine	N			Possible HMX biodegradation intermediates
1,1-dimethylhydrazine	N			Anaerobic biodegradation product 1/2 life ~8 hrs A, 22 days, S, SW, 44 days GW[7,11,37]
Ammonium 2,4,6-trinitrophenoxide /	Y	8330	sol 1.4g/l	Little current use
2,4,6-Trinitrophenol (AP/PA)				
2,4,6-Trinitrocyclohexanone	N			Biodegradation product[12] standard not available
Picramic acid(2-amino-4,6-dinitrophenol)	N		sol <1g/l	Anaerobic degradation product[20] , standard not available
2,4-Dinitrophenol	Y	OC21B	sl. sol	Aerobic breakdown product target analyte
Common Child Constituents				
Formaldehyde	N		sol	Half life 7days S SW, 17 days GW[17]
Nitrate, nitrite	Y	353.2M	sol	Target analytes
Smokes				
Hexachloroethane	Y	OC21B	sol. 0.09g/l	Target analyte
Hexachlorobenzene	Y	OC21B		Degradation product, target analyte
Tetrachloroethylene	Y	OC21V		Degradation product, target analyte
Carbon tetrachloride	Y	OC21B		Degradation product, target analyte
Phosgene	N		sl sol	Minor degradation product. 1/2 life=1 K171hr S SW.GW[37]
Red phosphorus	N	*No specific*[34]	Insol	Used in match heads
Phosphorus oxy acids	Y	365.2	sol.	Predominant decomposition product in moist air is orthophosphate
White phosphorus	N	*7580(GC/NPD)*	sol: 33 mg/l	Ignites in air, 0.007-0.015% of total WP from detonation deposited as WP[34]
Phosphorus pentoxide, P_4O_{10}	N			Combustion product, unstable in air, decomposes to oxyacids
Phosphorus oxy acids	Y	365.2	sol.	Orthophosphoric acid predominant

TABLE 2-1

Typical Explosive, Propellant, and Pyrotechnic Compounds

Constituents of Munitions	Phase I Analyte	Method$^{(a)}$	Mobility$^{(b)}$	Comments$^{(c)}$
Smokes (cont.)				
Phosphine	N		sl sol gas	Toxic gas, slow generation in water, rapid volatilization, reacts with O_2
Titanium dioxide	N		insol.	Non-toxic, white paint pigment
Brass	Y	IM40MB	insol	Copper, zinc on target analyte list
Polyethylene glycol (PEG 200)	N	*HPLC/UV*^{34}	sol	Mol Wt range used 190-210, used in cosmetics, ointments
Diesel Smoke	Y	OC21B/OC21V	sl sol	Contains target analyte BTEX, PAHs hydrocarbons
Fog Oil	Y	SVOCs	insol.	Predominantly aliphatics, low levels of target analyte PAH
Graphite Smoke	N		insol	Elemental carbon, non-toxic
Dyes				
Old Dyes				
Red: Disperse Red Dye 9 (methylaminoanthraquinnone, MAA)	Y	SVOC TIC	sol = 0 1mg/l. logK_{ow}=4 1	60-75% photolysis loss in 50 hrs. anaerobic 1/2 life <20 days
Anthraquinone	Y	SVOC TIC	insol	Impurity (25%) in MAA, biodegradable
Aminoanthraquinone	Y	SVOC TIC	insol	Combustion and photolysis product, photolyzes more rapidly than MAA
Violet: Disperse Violet 1, 1 4-diaminodihydroanthraquinone (DDA)	N		sol = 0 3mg/l. logK_{ow}=3 3	100% conversion to DAA during detonation
1,4-Diaminoanthraquinone (DAA)	N			Photolysis to aminoanthraquinone, anaerobic 1/2 life of 15 days
Yellow: Benzanthrone (BZA)	Y	SVOC TIC	insol	Unchanged during detonation. short photolysis half-life
Vat Yellow 4 (Dibenzochrysenedione, DBC)	N		insol	Unchanged during detonation
Green: Solvent Green 3 (1 4-di-p-toluidine-9,10-anthraquinone)	N		sol =9•10^{7}mg/l. logK_{ow}=8 5	FDA approved for use in cosmetics, externally applied drugs, contact lenses Unchanged during detonation Rapid photolysis in natural sunlight
New Dyes				
Red: Sudan R, Solvent Red 1 (o-methoxy-phenyl-azo-b-naphthol)	N		sol = 3•10^{4}mg/l. logK_{ow}=6 4	Unchanged during detonation. rapid photolysis
Disperse Red 11(1,1-diamino-2-methoxyanthraquinone)	N		sol = 0 5mg/l. logK_{ow}=3 5	30-40% loss from photolysis in soil over 50 hours, anaerobic degradation 1/2 life 10 days
o-anisidine	Y	SVOC TIC	sol = 14g/l	hydrolysis product, binds irreversibly to humic materials in soil. rapidly photolyzed in sunlight
1-amino-2-naphthol	N		sol	hydrolysis product, binds irreversibly to humic materials in soil. rapidly photolyzed in sunlight
Yellow: Solvent Yellow 33 (QID, 2,2-quinolyl-1,3-indandione)	N		sol = 0 17mg/l. logK_{ow}=3 5	Forms complexes with metals in soil or sediments
Green: Solvent Green 3 (see above)	N			
Additional Dyes				
Auramine, Basic Yellow 2 (tetramethyl-p-diaminobenzophenone)	N		insol	Photolysis 1/2 life=1 9 hours, biodegrades in water.soil. binds strongly to humic materials
Basic Red 1, Rhodamine 6G	N		sol	Strongly fluorescent dye, FDA approved for cosmetics. topical drugs
CI Disperse Yellow 3 (p-acetamidophenyl-azo-m-methyl-o-phenol)	N		K_{ow}=4 3	Azo dye photoreactive, anaerobically degraded
Yellow/white coumarin	N		likely soluble	Dye containing fluorescent derivative of coumarin, may be detectable as TIC
Fugitive yellow/white	N		soluble	Polymeric ethoxylated azo dye, used in detergents, agricultural chemicals, biodegradable
Tear gas				
Chloroacetophenone (CN)	Y	SVOC TIC	insol ; log Pow=2 08	1/2 life=4 wks S. SW, 8 wks GW^{33}
Chlorobenzylidenemalononitrile (CS)	N	*HPLC/UV*^{34}	sl sol	Rapidly hydrolyzes, settled dust remains active for up to 5 days^{34}
2-Chlorobenzaldehyde	N	*SVOC*		CS degradation product
Dibenz(b,f)-1,4-oxazepine (CR)	N	*GC/FID/NPD*^{34}	sl. sol	1% of CR formulation; difficult to decompose. not used at site
Propylene glycol	N	*HPLC/UV*	sol.	80% of CR formulation, non-toxic, used in pharmaceuticals, foods, cosmetics, rapidly biodegrades

TABLE 2-1
Typical Explosive, Propellant, and Pyrotechnic Compounds

Constituents of Munitions	Phase I Analyte	Method[(a)]	Mobility[(b)]	Comments[(c)]
Ordnance Chemicals/Additives/Fillers				
Acetone	Y	OC21V	Misc.	Target compound
Aluminum	Y	IM40MB	Insol.	Aluminum on TAL
Aluminum alloy	Y	IM40MB	Insol.	Aluminum on TAL
Aluminum foil	Y	IM40MB	Insol.	Aluminum on TAL
Aluminim powder	Y	IM40MB	Insol.	Aluminum on TAL
Aluminum tape	Y	IM40MB	Insol.	Aluminum on TAL
Aluminum-nickel-copper-zinc alloy	Y	IM40MB	Insol	Aluminum, copper, nickel on TAL
Ammonium nitrate	Y	353.2M/350.2	Sol.	Ammonia, nitrate on TAL
Ammonium perchlorate	Y(NH_4^+)	353.2M	Sol	Present in White B smoke at 40%; perchlorates added as Phase 2 analyte
Antimonial lead	Y	IM40MB	Insol.	Antimony, lead on TAL
Antimony	Y(Sb)	IM40MB	Insol.	Antimony on TAL
Antimony sulfide	Y	IM40MB	Insol.	Antimony on TAL
Asbestos	N		Insol.	
Asphalt compound, asphaltum	N		Insol.	PAH in asphalt on SVOC TCL, present in White B smoke at 26%
Barium	Y	IM40MB	Insol.	Barium on TAL
Barium chromate	Y	IM40MB	Insol	Barium, chromium on TAL
Barium nitrate	Y	IM40MB/353.2	Sol.	Barium on TAL
Barium peroxide	Y	IM40MB	Insol	Barium on TAL; peroxide decomposes in contact with water and air
Barium stearate	Y	IM40MB		Barium on TAL
Boron, boron amorphous powder	Y	IM40MB	Insol	Boron on TAL
Brass	Y	IM40MB	Insol	Copper-zinc alloy
Butyl acetate, butyrate dope, butyrate thinner	Y	VOC TIC	Sl.sol	Solvent for lacquers
Cadmium chromate	Y(Cd)	IM40MB		Cadmium, chromium on TAL
Calcium	Y	IM40MB		Ingnites in air, TAL metal
Calcium carbonate	Y	IM40MB/310.1	Insol.	Limestone/chalk, Ca on TAL - non-toxic
Calcium resonate	Y(Ca)	IM40MB		Calcium on TAL
Calcium silicide	Y(Ca)	IM40MB		$CaSiO_3$, calcium on TAL, silicates insoluble
Calcium stearate	Y(Ca)	IM40MB	insol.	Calcium on TAL, stearates non-toxic
Camphor	Y	SVOC TIC	Insol.	Natural product, used as plasticizer
Carbon black	N		insol	Graphite, non-toxic - absorbed PAH on target list
Castor oil	N		insol.	Natural product, therapeutic agent; used in Type II flares at 1.1%
Charcoal	N		insol	Carbon
Chromate coating	Y	IM40MB		Chromium on TAL
Chromate passivation treatment	Y	IM40MB		Chromium on TAL
Chromium	Y	IM40MB	Insol	Chromium on TAL
Chromium oxide	Y(Cr)	IM40MB	Insol.	Chromium on TAL
Coal	N		Insol	PAH and metals in coal on SVOC TCL and TCL
Cobalt naphthalene	Y	IM40MB /OM31B		Cobalt on TAL; naphthalene of TCL
Copper	Y	IM40MB	Insol	Copper on TAL
Copper alloy	Y	IM40MB	Insol.	Copper on TAL
Copper alloy clad steel	Y	IM40MB	Insol.	Copper, iron on TAL
Copper plated steel	Y	IM40MB	Insol.	Copper, iron on TAL
Copper-beryllium alloy	Y	IM40MB	Insol.	Copper, beryllium on TAL
Corn starch	N			Foodproduct

TABLE 2-1
Typical Explosive, Propellant, and Pyrotechnic Compounds

Constituents of Munitions	Phase 1 Analyte	Method[(a)]	Mobility[(b)]	Comments[(c)]
Ordnance Chemicals/Additives/Fillers(cont.)				
Cupric salicylate	Y(Cu)	IM40MB	sol.	Copper on TAL
Dibutyl phthalate	Y	OC21B		Target analyte, present in propellant at 8%
Diethylphthalate	Y	OC21B		Target analyte: present in M8 propellant at 3%
Diethylhexylphthalate	Y	OC21B		Plasticizer
Di-n-propyl adipate	Y	SVOC TIC	insol.	Used as plasticizer in M-14 propellant, 0 4%
Diphenyl amine	Y	OC21B	insol	Used as stabilizer, indistinguishable during analysis from N-nitroso diphenyl amine
Elgiloy (cobalt alloy)	Y	IM40MB	Insol	Cobalt on analyte list
Ethyl acetate	Y(TIC)	VOC TIC	sol	
Ethyl centralite (diethyldiphenyl urea)	N	*TLC/HPLC*	insol	0 02-6 5% of solid propellant
Ethylene alcohol (ethylene glycol)	N		sol.	1/2 life= 12 days S, SW,24 days GW[17]
Ethylene dimethacryl (ethylene glycol dimethacrylate)	Y	SVOC TIC	sol	Reactive monomer for polyester
Fuze Powder (Charcoal/ammonium nitrate)	Y(NH_4NO_3)	350 2	Sol	
Graphite	N			Elemental carbon - non-toxic
n-Hexane	Y	VOC TIC		
Iconel (Nickel/chromium/iron alloy)	Y	IM40MB	insol	Nickel, chromium iron on TAL
Iron	Y	IM40MB	insol.	TAL
Iron oxide, iron oxide black, iron oxide red	Y(as Fe)	IM40MB	insol	rust - iron on TAL, non-toxic
Iron phosphate	Y	IM40MB/365 2		Iron and phosphates on target analyte list
Isobenzofurandione (Phthallic anhydride)	N		sl sol	Hydrolyzes to phthallic acid, both would be detected as SVOC TIC if present
Lactose	N			Milk sugar - non-toxic
Lead	Y	IM40MB	insol	Lead on TAL
Lead alloy	Y(asPb)	IM40MB	insol	Lead on TAL
Lead antimonate	Y	IM40MB	insol	Lead and antimony on TAL
Lead azide	Y(asPb)	IM40MB	insol	Lead on TAL
Lead chromate	Y(asPb)	IM40MB	insol	Lead on TAL
Lead dioxide	Y(asPb)	IM40MB	insol	Lead on TAL
Lead peroxide	Y(asPb)	IM40MB	insol.	Lead on TAL
Lead red (lead tetroxide); red lead oxide	Y(asPb)	IM40MB	insol.	Lead on TAL
Lead resorcylate	Y(asPb)	IM40MB	insol	Lead on TAL: resorcylic acid as SVOC TIC, ~2% of post-1965 PRJ and M-14 propellants
Lead salicylate	Y(asPb)	IM40MB	Low sol.	Lead on TAL, burning rate modifier in double-base propellants
Lead salt - DNOC (dinitrocresol)	Y	IM40MB		Lead and 4 6-dinitro-2-methylphenol (DNOC) on TAL.
Lead stearate	Y(asPb)	IM40MB	Low sol.	Lead on TAL; burning rate modifier in ROLAND propellants:
Lead styphnate(lead trinitroresorcinate), lead styphnate normal	Y(asPb)	IM40MB		Lead on TAL, trinitroresorcinol as SVOC TIC (standard unavailable)
Lead thiocyanate	Y(asPb)	IM40MB	Sol 0.5%	Lead on TAL
Lead-sodium dinitro ortho	Y(asPb)	IM40MB		Lead on TAL
Linseed oil	N		Low sol	Natural product, glycerides of C14-C18 hydrocarbon acids, toxic due to metal contaminants
Magnesium, magnesium powder	Y	IM40MB		Burns in air, magnesium on TAL
Magnesium carbonate	Y(as Mg)	IM40MB	insol	Magnesium on TAL
Manganese dioxide	Y (as Mn)	IM40MB	insol	Reactive, manganese on TAL
Methyl centralite (dimethyldiphenyl urea)	N		insol	Used as stabilizer for nitrocellulose-based explosives, standard not available
Methyl ethyl ketone	Y	VOC	misc.	On target analyte list
Molybdenum	Y	IM40MB	insol	TAL
Molybdenum nitrate	Y	IM40MB /353 2	sol.	TAL
n-Amyl alcohol	N		sl. sol	Used as stabilizer prior to WWII, natural component of many foods, biodegradable
Nickel alloy, nickel coating, nickel plating	Y	IM40MB	insol	TAL
Nitrile	N		insol.	Term generally refers to nitrile rubber
Nitrocellulose(NC), nitrocellulose solution (Collodion)	N			Used as topical protectant; complex mix of polynitrated celluloses, biodegrades

TABLE 2-1
Typical Explosive, Propellant, and Pyrotechnic Compounds

Constituents of Munitions	Phase 1 Analyte	Method[a]	Mobility[b]	Comments[c]
Ordnance Chemicals/Additives/Fillers (cont.)				
2-Nitrodiphenyl amine	Y	SVOC TIC	insol	Stabilizer for PRJ and M-14 propellant. 0 6-3% of formulation
Nitrotoluenes	Y	OC21B		Target compounds
Oxamide(oxalic acid amide)	N			Rapidly degrades to oxalic acid. precipitates as calcium oxalate
Phlogopite	N		insol.	Natural mineral(mica). high in Mg
Phosphate coating	Y	365 2		Phosphates target analytes
Phosphor bronze alumina	Y		insol	Al on TAL
Platinum alloy	N		insol.	Used in jewelry
Platinum-palladium-silver	Y(Ag)	IM40MB	insol.	Silver on TAL
Potassium chlorate	Y(K)	IM40MB	sol.	Potassium on TAL
Potassium dinitrobenzofuroxan (KDNBF)	N		sol 2.4g/l	M207 charge (0 09 g) No US production after '77.unstable compound.standard unavailable
Potassium nitrate	Y	IM40MB /350 2M	sol	Potassium and nitrates on TAL. present in propellant <1.5%
Potassium perchlorate	Y(K)	IM40MB	sol.	Potassium on TAL; perchlorates added as Phase 2 analyte
Potassium salt	Y	IM40MB	sol.	Potassium on TAL
Potassium sulfate	Y	IM40MB/300 0	sol	Potassium and sulfates on TAL; present in propellant at <1%
Silica, silicon dioxide	N		insol.	Sand
Silicon	N		insol	
Silver	Y	IM40MB	insol	TAL
Sodium	Y	IM40MB	Reacts w water	Sodium on TAL., burns in air
Sodium bicarbonate	Y	IM40MB/310 1	sol.	Sodium on TAL; baking soda
Sodium carbonate monohydrate	Y	IM40MB /310 1	sol	Sodium on TAL. baking powder
Sodium nitrate	Y	IM40MB/353 2M	sol	Sodium on TAL.
Sodium oxalate	Y(Na)	IM40MB	sol	Used in trip flares at 5-16%: oxalate precipitates as calcium salt in soil
Sodium salicylate	Y(Na)	IM40MB	sol	Sodium on TAL
Sodium sulfate	Y	IM40MB/300 0	sol	Sodium on TAL
Stearic acid	Y	SVOC TIC	sl sol	Natural fatty acid
Strontium	N		Reacts w water	Used in small (1 g) quantities in flares: burns spontaneously in air. reacts with water
Strontium nitrate; strontium nitrate, anhydrous	Y(NO_3^-)		Sol.	
Strontium oxalate	N		sl.sol	Oxalate ion biodegrades
Strontium peroxide	N		sl. sol.	Decomposes in air
Styphnate	N		insol	Salt of 2 4,6-trinitroresorcinal
Sugar	N			Non-toxic
Sulfur	Y	SVOC TIC	insol.	
Talc (magnesium silicate)	Y(Mg)			Non-toxic
Tetracene (2,3-benzanthracene)	Y	SVOC TIC	insol	PAH, sensitizer for explosives
Tetrachlorozincate (salt of complex ion $ZnCl_4^{-2}$)	Y	IM40MB/300 0	sol	Hydrolyzes readily to Cl^- and Zn^{+2}
Tetranitrocarbazole	N			Ingredient of igniter mix, reactive: standard unavailable
Tin-lead solder	Y(Pb)	IM40MB		
Titanium, titanium powder, titanium technical	N		insol	
Toluene	Y	OC21V	sl sol	Target analyte
Toluidine red toner (Pigment Red 3)	N		insol	Widely used to color inks, ruber, plastics: bound up in polymeric matrix
Triacetin (1,2,3-propanetriol triacetate)	Y	SVOC TIC	sol.	Plasticizer in PRJ propellant (8%). topical antifungal. 1/2 life 2 days A. 130 days SW, moist S
Tungsten	N		insol.	Inert metal
Vinyl alcohol	N		sol	Monomer for polyvinyl alcohol. does not exist as stable compound
Vinyl acetate	Y	OC21V	sol	Target analyte
White lead(lead hydroxide carbonate)	Y(Pb)	IM40MB	insol	Pb target analyte

TABLE 2-1
Typical Explosive, Propellant, and Pyrotechnic Compounds

Constituents of Munitions	Phase I Analyte	Method[a]	Mobility[b]	Comments[c]
Ordnance Chemicals/Additives/Fillers (cont.)				
Zinc, zinc dust	Y	IM40MB	insol.	Target analyte
Zinc alloy	Y(Zn)	IM40MB	insol	Zn-Target analyte
Zinc chromate	Y(Zn)	IM40MB	sl sol	Zn-Target analyte
Zinc oxide	Y(Zn)	IM40MB	insol.	Zn target analyte, used in topical cremes
Zinc phosphate	Y	IM40MB/365 2	insol	Target analytes
Zinc stearate	Y(Zn)	IM40MB	insol	Zn-Target analyte stearates non-toxic
Zirconium, zirconium powder	N		insol	High heat and corrosion resistance+K243
Zirconium hydride	N		insol	Stable in presence of water
Zirconium-nickel alloy, alloy powder	Y(Ni)	IM40MB	insol	Ni on TAL
Detonation Contaminants/Combustion Products[33]				
VOCs				
Acetic acid	N		misc	Acetate half life=7 days S WS 14 days GW
Acetone	Y	OC21V		
Acetylene	N			Released as reactive insoluble gas would not persist
Acrolein	Y	VOC TIC		Released as gas, would not persist - 1/2 life = 4 wks S SW 8 wks GW
Benzene	Y	OC21V		Target analyte
1,3 Butadiene	N			Released as reactive, insoluble gas, would not persist
iso- Butane	N			Released as insoluble gas, would not persist
n- Butane	N			Released as insoluble gas, would not persist
2- Butanone	Y	OC21V		Target analyte for VOC analysis
1- Butene	N			Released as insoluble gas, would not persist
iso- Butene	N			Released as insoluble gas, would not persist
trans-2- Butene	N			Released as insoluble gas, would not persist
Carbon disulfide	Y	OC21V		Target analyte for VOC analysis
Carbonyl sulfide	N			Reactive gas, would not persist
Chloromethylbenzene	Y	VOC TIC		Product from red dye combustion
Cyclohexane	Y	VOC TIC	insol	
Cyclopentane	Y	VOC TIC	insol	
Cyclopentanone	Y	VOC TIC		
Decanal	Y	VOC TIC		
n- Decane	Y	VOC TIC		
Dichlorodifluoromethane	Y	VOC TIC		
2,3- Dihydro-1-methyl-1H-indene	Y	VOC TIC		
2,3- Dihydro-4-methyl-1H-indene	Y	VOC TIC		
2,2 Dimethylbutane	Y	VOC TIC		Released as insoluble gas, would not persist
2,3- Dimethylbutane	Y	VOC TIC		Released as insoluble gas, would not persist
2,3- Dimethylhexane	Y	VOC TIC		
2,5- Dimethylhexane	Y	VOC TIC		
2,3- Dimethylpentane	Y	VOC TIC		
2,4- Dimethylpentane	Y	VOC TIC		
Ethane	N			Released as insoluble gas, would not persist
Ethylbenzene	Y	OC21V		Target analyte for VOC analysis
Ethylene	N			Released as reactive insoluble gas, would not persist
m- Ethyltoluene	Y	VOC TIC		
o- Ethyltoluene	Y	VOC TIC		

TABLE 2-1
Typical Explosive, Propellant, and Pyrotechnic Compounds

Constituents of Munitions	Phase 1 Analyte	Method$^{(a)}$	Mobility$^{(b)}$	Comments$^{(c)}$
Detonation Contaminants/Combustion Products (cont.)				
p- Ethyltoluene	Y	VOC TIC		
2- Furaldehyde	Y	VOC TIC		
Heptanal	Y	VOC TIC		
n- Heptane	Y	VOC TIC		
n- Hexane	Y	VOC TIC		
1- Hydroxy-2-propanone	Y	VOC TIC		
Indane	Y	VOC TIC		
2- Methyl-1-butene	Y	VOC TIC		
Methylcyclohexane	Y	VOC TIC		
Methylcyclopentane	Y	VOC TIC		
Methylene chloride	Y	OC21V		Target analyte
2- Methylheptane	Y	VOC TIC		
2- Methylhexane	Y	VOC TIC		
3- Methylhexane	Y	VOC TIC		
Methylnitrate(nitromethane)	Y	VOC TIC		Reactive gas, would not persist
3- Methylpentane	Y	VOC TIC		
MTBE	Y	8021W		target analyte
Nitromethane	Y	VOC TIC		Released as unstable gas, not persistent
Nonanal	Y	VOC TIC		
n- Nonane	Y	VOC TIC		
Octanal	Y	VOC TIC		
n- Octane	Y	VOC TIC		
n- Pentane	Y	VOC TIC		
Propane	N			Released as insoluble gas, wouldnot persist
Propene	N	VOC TIC		Released as reactive, insoluble gas, wouldnot persist
iso- Propylbenzene	Y	VOC TIC		
n- Propylbenzene	Y	VOC TIC		
Styrene	Y	OC21V		Target analyte for VOC analysis
Tetrachloroethylene	Y	OC21V		Target analyte for VOC analysis
Toluene	Y	OC21V		Target analyte for VOC analysis
Trichlorofluoromethane	Y	VOC TIC		
1,3,5- Trimethylbenzene	Y	VOC TIC		
1,2,4- Trimethylbenzene/sec-butylbenzene	Y	VOC TIC		
2,2,4- Trimethylhexane	Y	VOC TIC		
2,2,4- Trimethylpentane	Y	VOC TIC		
2,3,4- Trimethylpentane	Y	VOC TIC		
m&p- Xylene	Y	OC21V		Target analyte for VOC analysis
o- Xylene	Y	OC21V		Target analyte for VOC analysis
SVOCs				
Acenaphthylene	Y	OC21B		Target analyte
Acetophenone	Y	SVOC TIC	sl. sol	Would be detected as TIC; used in perfumes
Benzothiophene	Y	SVOC TIC	sl. sol.	Product of red dye combustion
Benzyl alcohol	Y	OC21B		Target analyte
Butylbenzylphthalate	Y	OC21B		Target analyte
Diethylphthalate	Y	OC21B		Target analyte
Di-n-butylphthalate	Y	OC21B		Target analyte
Fluorene	Y	OC21B		Target analyte

TABLE 2-1

Typical Explosive, Propellant, and Pyrotechnic Compounds

Constituents of Munitions	Phase I Analyte	Method[a]	Mobility[b]	Comments[c]
Detonation Contaminants/Combustion Products (cont.)				
2- Methylnaphthalene	Y	OC21B		Target analyte
3&4- Methylphenol	Y	OC21B		Target analyte
Naphthalene	Y	OC21B		Target analyte
N-nitrosodiphenylamine	Y	OC21B		Target analyte
Phenanthrene	Y	OC21B		Target analyte
Phenylactealdehyde	Y	SVOC TIC	sl. sol.	Polymerizes on standing, used in perfumes
Inorganic Gases				
Sulfur dioxide	N			Released as gas, would not persist
Carbon monoxide	N			Released as gas, would not persist
Nitrogen oxides (No$_x$)	N			Released as gases, would not persist
Cl_2	N			Released as reactive gas, would not persist
HCl	Y(Cl^-)	300.0		Indirectly measured via pH and chloride ion
Metals				
Aluminum	Y	IM40MB		Target analyte
Antimony	Y	IM40MB		Target analyte
Arsenic	Y	IM40MB		Target analyte
Barium	Y	IM40MB		Target analyte
Beryllium	Y	IM40MB		Target analyte
Cadmium	Y	IM40MB		Target analyte
Chromium	Y	IM40MB		Target analyte
Cobalt	Y	IM40MB		Target analyte
Copper	Y	IM40MB		Target analyte
Lead	Y	IM40MB		Target analyte
Magnesium	Y	IM40MB		Target analyte
Manganese	Y	IM40MB		Target analyte
Mercury	Y	IM40HG		Target analyte
Nickel	Y	IM40MB		Target analyte
Phosporus	Y	365.2		Target analyte
Selenium	Y	IM40MB		Target analyte
Zinc	Y	IM40MB		Target analyte
Aluminum oxide	Y	IM40B (Al)		Al - Target analyte
Iron oxide	Y	IM40B (Fe)		Fe - Target analyte
Lead oxide	Y	IM40B (Pb)	insol.	Pb - Target analyte
Zinc chloride	Y	IM40B/300.0	sol	Zn, Cl - Target analytes, used in deodorants, astringents
Zinc oxide	Y	IM40B (Zn)	insol.	Zn -Target analyte, used as topical protectant

TABLE 2-1
Typical Explosive, Propellant, and Pyrotechnic Compounds

Constituents of Munitions	Phase I Analyte	Method[(a)]	Mobility[(b)]	Comments[(c)]
Construction Materials				
Acetal				Plastic copolymer
Acetal molding				Plastic copolymer
Acrylic cloth				Polymeric fabric
Adhesive (926269)				Polymeric material after curing
Adhesive (9322242)				Polymeric material after curing
Adhesive 3M				Polymeric material after curing
Adhesive cell nitrate				Polymeric material after curing
Adhesive MR23 (9255426)				Polymeric material after curing
Adhesive plastic				Polymeric material after curing
Adhesive proxseal (9272251)				Polymeric material after curing
Adhesive RTV (9233455)				Polymeric material after curing
Adhesive rubber (9322244)				Polymeric material after curing
Adhesive silicone RTV				Polymeric material after curing
Amplifier				
Animal glue				
Anodic coating				
Anti-seize compound				Typically a bentone-based grease with copper, lead or molybdenum sulfide
Bakelite DYNK polyethylene				Plastic
Bead chain				Metal chain used in soldering
Binder				Organic polymeric material, e g polybutylene, polyacrylates, polyurethanes
Bituminous coating				
Black oxide coating				
Book cover board				
Boxboard				
Brazing				Agents used in preparation of ceramic/metal parts; typically titanium or zirconium
Butyl rubber				Synthetic polymeric rubber
Capacitor tantalum chip				
Carborundum				
Celcon GR-20 (plastic ring)				Polymeric material
Cellofilm 4430				
Cellophane				
Cement (9266688)				Polymeric material after curing
Cement Pettman				Polymeric material after curing
Ceramic				
Chip darlington				
Chip diode				
Chip integrated circuit				
Chip transistor				
Chip board				
Coating compound				
Cork				
Corrosion preventative compound				
Corrugation				
Cotton, cotton cloth				
Ctg paper				
Deterrent				
Desensitizing wax				

TABLE 2-1
Typical Explosive, Propellant, and Pyrotechnic Compounds

Constituents of Munitions	Phase 1 Analyte	Method$^{(a)}$	Mobility$^{(b)}$	Comments$^{(c)}$
Construction Materials (cont.)				
Diatomaceous earth				
Elastomer seal				
Enamel				Organic polymeric material and metal pigments after drying (metals on TAL)
Enamel, green, blue, brown				Organic polymeric material and metal pigments after drying (metals on TAL)
Epoxy conductive				Polymeric material after curing
Epoxy lead stake				
Epoxy polyamide				Surface-coating polymeric material
Ethylene-propylene				Polymeric hydrocarbon
Felt, wool felt, hair felt				Natural product fabric
Fiber acrylic				Synthetic polymeric fiber
Fiber board				
Fiber craft				
Fiber polyester				
Fiberglass				
Filler IF6B				
Fish paper				
Flour paste				
Formaldehyde/melamin				Polymeric plastic material
Gilding metal				
Gold bonding wire				
Gold conductor ink				
Gold plating				
Grease				Likely silicone or hydrocarbon based material
Ground glass				
Guar gum				Natural product
Gum red				Natural product
Gummed paper				
Herculon fiber				Synthetic polyester fiber
Ink conductor				Minute levels of pigments after dried
Ink marking				Minute levels of pigments after dried
Ink printer				Minute levels of pigments after dried
Insulating compound				
Insulation				
Irradiated polyolefin				Polymeric material
Jute				
Kapton copper/plastic				
Kraft paper				
Lacquer green				Polymeric material and metal pigments after lacquer is dried
Lacquer red				Polymeric material and metal pigments after lacquer is dried.
Laminac				Thermosetting resin. cures to polyester/polystyrenecompolymer
Laquer cell nitrate				
Lexan				Plexiglass
Loctite (9340431)				Adhesive - polymeric when cured
Loctite (9370176)				Adhesive - polymeric when cured
Lube oil				Petroleum hydrocarbon product
Lubersol DDM				Catalyst mix for optical lens cement. methyl ethyl ketone peroxide. not present after cement cures
Lubricant (plast-o-lon)				
Lubricant fluorocarbon (11722967)				Fluorinated hydrocarbon mix

TABLE 2-1
Typical Explosive, Propellant, and Pyrotechnic Compounds

Constituents of Munitions	Phase I Analyte	Method[a]	Mobility[b]	Comments[c]
Construction Materials (cont.)				
Lubricant mixture (11723115)				
Lubricant Vydax #525				
Lubricating mixture				
Lubricating oil				Typically petroleum hydrocarbons
Metal foil				
Mold release (11722937)				Typically silicone grease, zinc stearate or polymeric films
Molded polystyrene				Hard polymeric plastic
Nylon				
Nylon coating				Polymeric material
Nylon glass filled				Polymeric material
Nylon parachute cloth				Polymeric material
Overglaze ink				
P lead b				
P18 oil gel				
Paper				
Paper fluorescent				
Paper onion skin				
Paper parrafined				
Paper sealing				
Parachute cloth				
Parlon (chlorinated isoprene rubber)				Synthetic rubber
Plastic				Synthetic polymer
Plastic thermosetting				Polymeric material cured with heat
Polybutadiene neoprene				Synthetic rubber
Polycarbonate resin				Hard, transparent polymeric material
Polyester resin catalyst accelerator				Typically trace level of acid added to polymerization
Polyethylene foam				Polymeric material
Polyisobutylene, polyisobutylene binder				Polymeric material
Polytetrafluoroethylene (Teflon)				Fluorinated polymeric material
Polytrifluor				Fluorinated polymeric material
Polyurethane foam				Polymeric material
Polyvinyl				Generic class of polymers
Polyvinyl chloride				Polymeric material
Polyvinyl resin				Polymeric material
Potting foam				Polymeric material
Powder heat				
Powder metal, powder metal 30/50				
Powder metal ellipsoidal				
Powder smokeless				
Process oil				
Prong-lok #4 (seal metallic)				
Rareox				
Red gum				Eucalyptus gum, used as astringent
Resin additives				Trace levels of antioxidants, plasticizers, etc held in polymeric matrix of cured resins
Resin polyester				Polymeric material,inert
Resin polysulfone				Heat-resistant polymeric material, inert
Resistor ink				
Rubber				Polymeric material

TABLE 2-1

Typical Explosive, Propellant, and Pyrotechnic Compounds

Constituents of Munitions	Phase 1 Analyte	Method[a]	Mobility[b]	Comments[c]
Construction Materials (cont.)				
Rubber chlorinated				Polymeric material
Sealant waterproof				Silicone or hydrocarbon grease based coatings
Sealer				
Sealer (9220862)				
Sealing compound				
Shellac				Organic polymeric material after drying
Silicone compound				
Silk cloth				
Silver braze				Silver on TAL
Silver coating				Silver on TAL
Solder cream				
Solvent				Generic term; solvents on TAL for volatile organics
Spring steel				Metals on TAL
Stainless steel				Metals on TAL
Steel				Metals on TAL
Stencil ink, black, white/yellow				Trace levels of carbon (black) or dyes after ink is dried
Tape adhesive				
Tape polyester				
Tape pressure sensor				
Teflon-coated fiberglass tape				
Thinner dope/lacquer				Organic solvent e g butyrate esters, not present after lacquer is dried
Thread cotton				
Thread polyester				
Thread silk				
Transistor				
Twine linen waxed				
Varnish, varnish phenolic				Organic polymeric material when dried
Vinsol				Natural resin from pinewood
Vinylite				Polyvinyl plastic
Viton				Fluorinated polymer; inert
Waterproofing compound				Silicone or hydrocarbon based materials
Wax				Beeswax, parafin, synthetic hydrocarbon waxes
Wax candelilla				Natural product, hydrocarbon wax
Wood, wood wirebound				

TABLE 2-1

Typical Explosive, Propellant, and Pyrotechnic Compounds

Constituents of Munitions	Phase I Analyte	Method[a]	Mobility[b]	Comments[c]

Footnotes

(a) Methods for target analytes are provided for the water matrix. Methods in italics are those suggested by literature sources for non-target analytes.
The following abbreviations are used.
SVOC TIC = Would, if present, be tentatively identified by library search of mass spectral data from OC21B analysis for semivolatile organics.
VOC TIC = Would, if present, be tentatively identified by library search of mass spectral data from OC21V analysis for volatile organics.

(b) Mobility information is provided from literature sources and is generally qualitative based upon the likelihood that a compound or material would be dissolved to a measurable degree.
This information was not compiled for those chemicals already on the target analyte list
The following abbreviations are used.
sol. = soluble
insol. = insoluble
sl. sol. = slightly soluble, generally < 1 g/l
misc. = miscible

(c) Comments are provided from literature sources noted and from the following general references:
Encyclopedia of Explosives and Related Items. U.S. Army Research and Development Command Tacom, ARDEC Picatinny Arsenal, New Jersey, USA
The Merck Index. Tenth edition, Merck&Co. Rahway, New Jersey, 1983
TOXNET (Toxicology Data Network) Hazardous Substances Data Bank. National Library of Medicine
Abbreviations included in comments are:
A= air; S=soil; SW = surface water, GW = groundwater

(d) Analysis recommendations are qualified as noted

Y[1]	Material contains a mix of constituents, some of which are on the Target Analyte List or would be detected as SVOC or VOC TICS
N[1]	Not a confirmed product or intermediate
N[2]	Intermediate in degradation
N[3]	Compound has short half-life, noted biodegradability or demonstrated reactivity; would not have persisted for time interval since last use
N[4]	Commercial standard unavailable
N[5]	Other product for degradation route included on analyte list as marker
N[6]	Released as gas; would not persist in water or soil
N[7]	Non-toxic or inert material
N[8]	Immobile, would not be transported to groundwater

Table 2-2

Camp Edwards Gun and Mortar Positions
Feasibility Study Work Plan

(Stateplane, NAD83, Zone 4151, meters)

Gun & Mortar Position ID	Easting (x-coordinates)	Northing (y-coordinates)	Area (acres)
Gun Positions			
GP-1-OLD	278105.97	825582.38	50
GP-2	277976.19	828752.44	51
GP-2-OLD	278440.22	825533.94	52
GP-3-OLD	278661.63	825490.38	53
GP-3-OLD	278848.84	826276.31	63
GP-4-OLD (Howe)	278648.91	826270.50	55
GP-4-OLD (Turpentine)	279655.70	826117.01	56
GP-5	278446.03	826364.63	57
GP-6	279237.50	826818.13	58
GP-7	278978.31	826870.56	17
GP-8	278454.09	826963.06	59
GP-9	279387.97	826210.94	
GP-10	279232.88	826232.56	60
GP-11	278979.69	826244.69	61
GP-12	278344.88	833265.94	62
GP-14	277806.72	833719.88	54
GP-15-OLD	278323.69	827471.75	64
GP-16	277610.63	833662.31	16
GP-17	279615.41	834303.63	65
GP-18	279418.34	834197.81	18
GP-19-OLD	277345.42	832756.43	66
GP-20	279135.94	833589.19	67
GP-22	280526.88	833929.94	68
GP-24	277073.47	828826.13	69
Mortar Positions			
MP-1	279828.22	827005.31	70
MP-1-OLD	278452.56	828886.38	71
MP-2	279325.44	827090.69	72
MP-2-OLD	276887.75	830391.69	73
MP-3	278496.47	828067.13	20
MP-3-OLD	277113.03	831499.30	74
MP-4	278487.72	828367.06	75
MP-5	278515.34	828820.69	21
MP-6	278516.97	828877.94	20
MP-7	278570.22	828969.88	76
MP-8	278507.28	829024.81	19
MP-9	282976.85	831031.13	77
Former F Range	278913.03	825575.06	78
Former H Range	281679.96	827699.35	79

Table 2-6 includes most of the known current and former firing positions for artillery and mortar, as identified in the Archive Search Report (USACE, 1999).

Table 2-3

Camp Edwards Training Areas and Ranges
Feasibility Study Work Plan

Designation	Location	Training Activities	Date of Usage	Other Range Designation`	Training Activities	Date of Usage	Workplan Phase
Current A Range	East of Burgoyne Rd at Wood Rd Intersection	MG	70s-90s	None			IIb Supplement
Former A Range	North side Wood Rd near Deep Bottom Pond Rd	A, R, MG, and S	41-70s	Gravity Anti-Tank Range	Same	Same	IIb
Current B Range	East of Burgoyne Rd south of current A Range	25M Rifle & Pistol	90s	None			IIb Supplement
Former B Range	North side of Monument Beach Rd near Canalview Rd	1000in MG, Rifle, Pistol	35-80s	Machine Gun "A"	Same	Same	IIb Supp
				MP-2	Mortar Position	80s-90s	G&MP FSP
Current C Range	East of Burgoyne Rd south of current B Range	25M Rifle & Pistol	86-90s	None			IIb Supplement
Former C Range	East of Frank Perkins Rd near Monument Beach Rd Intersection	1000 in. MG & Rifle	35-80s	None			IIb Supplement
Current D Range	East of Burgoyne Rd south of current C Range	10M MG & Rifle	86-90s	None			IIb Supplement
Former D Range	North of Frank Perkins Rd at Pine Hill	Rifle, 1000in MG & Pistol	35-80s	Anti-Aircraft Miniature Range	Same	Same	IIb
Current E Range	East of Burgoyne Rd south of current D Range	Pistol	86-90s	None			IIb
Former E Range	Northeast of Demolition Area 1	Practice A & R	41-50s	None			IIb
Former E Range	Pocassett Forestdale Rd between Frank Perkins and Turpentine Rds	SA	50s-60s 70s-80s	Current G Range	Same	80s-90s	IIb
Former E Range	North of Pocassett Forestdale Rd south of Demolition Area 1	1000in MG & Rifle	60s	Current H Range	Same	80s-90s	IIb
Former E-I Range	North of Pocassett Foresetdale Rd south of Demolition Area I	SA	70s-80s	Current H Range	Same	80s-90s	IIb
Former E-2 Range	At Demolition Area I	SA	70s	Demo Area I	D	70s-80s	IIb
Former E-3 Range	At Demolition Area 2 north of Gibbs	D	70s80s	Demo Area 2	Same	Same	IIb
Former F Range	Pocassett Forsetdale Rd at intersection with Turpentine Rd	1000in & 25M Rifle, Tank Table	60s-80s	Current I Range	25M Rifle	80s-90s	IIb Supplement
Former F Range	North of Herbert Rd between Turpentine & Frank Perkins Rds	A	30s-50s	None			G&M FSP

Table 2-3

Camp Edwards Training Areas and Ranges

Feasibility Study Work Plan

Designation	Location	Training Activities	Date of Usage	Other Range Designation`	Training Activities	Date of Usage	Workplan Phase
Current G Range	Northern side Pocassett east of Frank Perkins Rd Intersection	25M MG	80-90s	Former E Range	Same	50s-60s 70s-80s	IIb Supplement
Former G Range	Western side of Greenway Rd south of Wood Rd	Shotgun	70s-80s	Current O Range	Same	80s-90	IIb Supplement
GA/GB Ranges	North of Dolan Rd near Greenway Rd	Rifle	35-50s	Know Distance Range	Same	Same	IIb
GN1	Southern side of Howe Rd	Practice G	40s-50s	None			IIb
GN2	Northern side of Howe Rd	G	40s-50s	None			IIb
Current H Range	North side Pocassett south of Demolition Area 1	25M MG	80s-90s	Former E Range Former E-1 Range	MG & Rifle MG & Rifle	60s; 70-80s	IIb IIb
Former H Range	Unknown (Greenway Rd)	Rifle & MG	50-60s	Unknown			IIb
Former H Range	East side Greenway at near J-3 Range	M	42-50s	None			G&M FSP
Former H Range	West of Greenway Rd at J-3 Range	M	35-41	Current J-3 Range	DOD HE Testing	70s-90s	G&M FSP
Current I Range	North side Pocassett Forestdale Rd at intersection with Turpentine Rd	25M Rifle	80s-90s	Former F Range	25M & 1000in Rifle/Tank Table	60-80s	IIb Supplement
Former I Range	Greenway Rd between J-3 and M Range	G	70s-80s	Current L Range	G	80s-90s	IIb Supplement
Former I Range	Greenway Rd between L Range and N Range	1000in Anti Tank, A, G, MG, Rifle	35-70s	Current M Range Anti-Tank Range Camp Range I	Unknown Same Same	80s-90s Same Same	IIa IIb Supp IIb Supp
Current J Range	Northern side Pocassett Forestdale Rd west of K Range	Pistol	80s-90s	Air Force A	Pistol	70s	IIb Supplement
Former J Range	Western Side of Greenway Rd at N Range	SA	35-50s	Current N Range Musketry Range No. 1 J2 Range	Rifle Same DOD Rifle Testing	80s-90s 40s 60s-70s	IIb Supp IIb Supp J1, J2, J3 WP
Former J-1 Range	Western side of Greenway Rd	SA DOD Testing Range	40s-50s 60s-80s	Current M Range	Unknown		J1, J2, J3 WP
Former J-2 Range	Western side of Greenway Rd	SA DOD Testing Range	40s-50s 60s-80s	Current N Range	Rifle	86-90s	J1, J2, J3 WP
Current J-3 Range	Western side of Greenway Rd	DOD Testing Range	70-90s	Former H Range	Mortar	40s-50s	G&MP FSP
Current K Range	Northern side of Pocassett-Forestdale Rd east of Air Force A	Pistol	86-90s	Air Force B	Same	70s	IIb Supplement

Table 2-3

Camp Edwards Training Areas and Ranges
Feasibility Study Work Plan

Designation	Location	Training Activities	Date of Usage	Other Range Designation	Training Activities	Date of Usage	Workplan Phase
Former K Range	On Greenway Rd south of Wood Rd	R, G, A	60s	Current P Range	Pistol	80s-90s	IIb
Former K Range	On Greenway Rd north of Wood Rd	Rifle	40s-50s	None			IIb
KD (Known Distance) Range	North side Pocasset Forestdale Rd east of K Range	LAW, practice & HE M, MG	90s	CTP-1	Unknown	70s	
Current L Range	Western side Greenway north of J-3 Range	G	80-90s	Infiltration Course 2 Former I Range	SA & OHT G	40s 70s-80s	IIb
Former L Range	Gibbs Road east of SE/SW Ranges	SA	50-80s	None			IIb
Former L (Musketry Range 2) Range	Southern side of Gibbs Rd at intersection with Greenway Rd	Rifle	40-50s	L-1 Combat Firing Range 1	SA Unknown	41-50 49	IIb
L-2 Range	Jefferson Rd in Training Area B-11	SA	40s	Combat Firing Range 1	Unknown	49	IIb
L-3 Range	Gibbs Rd in Training Area B-11	SA	40s	Combat Firing Range 2	Unknown	49	IIb
L-4 Range	North of Gibbs in Training Area C-16	SA	40s	None			IIb
Current M Range	Western side Greenway south of N Range and north of L Range	Not Used	80s-90s	Former I Range Former J-1 Range	A, G, MG, Rifle SA/DODI testing	35-70s, 40-80s	IIb Supplement
Former M Range	Western side of Greenway Rd south of J-3 Range	Pistol	70s-80s 60s	Former M-2 Range Former M-1 Range	SA, Practice G SA, Practice G	40s-50s 40s-50s	IIb Supplement
M-1, M-2, M-3, & M-4	Western side of Greenway south of J-1 Range	MG, Rifle, Pistol, Practice G	40-50s	M Range	SA	60s-80s	IIb Supplement
Current N	Western side of Greenway north of M Range	25M Rifle	86-90s	Old J-1 (Transition) or Musketry Range 1, L-2	B, SA, SA, LAW, HE, PR, inert M, Rifle 25M	35-50s; 40-80s	DOD
Former N Range	South of Gibbs Rd adjacent to Training Area C-13	SA	67-79	SE/SW Ranges	MG & R	80s-90s	IIb Supplement
Current O Range	Western side Greenway Road	SG	86-90s	Former G Range	SG	70s-80s	IIb Supplement
Former O Range	South of Gibbs Rd adjacent to Training Area C-13	SA & MG	67-80s	SE/SW Ranges	MR & R	80s-90s	IIb Supplement
Current P Range	Western side Greenway Rd south of Wood Rd	Pistol	86-90s	Former K Range	Rifle, G, R, & SA	41-80s	IIb
Former P Range	South of Gibbs Rd, west of Current SE/SW Ranges	SA	67-80s	Current T Range	MG	80s-90s	IIb Supplement

Table 2-3

Camp Edwards Training Areas and Ranges
Feasibility Study Work Plan

Designation	Location	Training Activities	Date of Usage	Other Range Designation`	Training Activities	Date of Usage	Workplan Phase
Former Q Range	South of Gibbs Rd between Current T Range and IBC	R & MG	67-83	None			IIb Supplement
Former R Range	Southern side Gibbs Rd west of IBC	M, SA, MG, & Rifle	67-90	None			G&M FSP
Former S Range	Southern side of Gibbs Rd adjacent to Training Area C-14	R & G	67-89	Current U Range			IIb
Current S-E/S-W Ranges	South of Gibbs Rd across from Training Area C-15	MG & R	80s-90s	Former N Range Former O Range	SA SA & MG	67-79 67-80s	IIb Supp IIb Supp
Current T Range	Southern side of Gibbs Rd east of IBC	MG & SA	86-90s	Former P Range	SA	67-80s	IIb Supplement
Current U Range	South of Gibbs Rd near Burgoyne Rd Intersection	R	86-90s	Former S Range	R & G	67-89	IIb
IBC	Southern side of Gibbs Rd adjacent to Training Area C-15	G, P, R, M, & SA	80-90s	None			IIb
Demo Area 1	North of Pocasset-Forestdale Rd west of Turpentine Rd	Heavy Demolition	86-90s	Former E-2 Range	SA D	70s 70s-80s	I, IIa
Demo Area 2	North of Gibbs Rd in Training Area C-14	Light Demolition	86-90s	Former E-3 Range	D	70-80s	I
Demo Area 3	Along Avery, Ben's Hollow and Monument Beach Roads	Demolition	Unknown	None			IIb
Demo Area 4	Along Wheelock Road	Demolition	80s	None			IIb
Inactive Demo Sites	West side Frank Perkins Rd at Howe and Herbert Rds	Demolition	40s	None			IIb Supplement
Kittredge Road Grenade Courts	North of Kittredge Rd south of Truck Rd	G	41-50s	None			IIb
Mock Village	Northern side Jefferson Rd east of Barlow Rd	TNT blocks, G & P	40s	None			IIb
Air to Air Darts	North side of Wheelock Rd east of Turpentine Rd	Unknown	50s				IIb
Skeet Range 1	At Herbert & Turpentine Intersection	MG, SG, skeet gun	40s	None			IIb Supplement
Skeet Range 2	At Herbert & Frank Perkins	MG, SG, skeet gun	40s	None			IIb

Table 2-3

Camp Edwards Training Areas and Ranges
Feasibility Study Work Plan

Designation	Location	Training Activities	Date of Usage	Other Range Designation`	Training Activities	Date of Usage	Workplan Phase
	Intersection						Supplement
500-yard Rifle Range	South of Wood Rd west of Greenway Rd	SA	40s	None			IIb Supplement
Old Artillery Range	Between Mitton & Howe Rds	A	circa 41				IIb
Combat Training Area I	At Pocasset-Forestdale & Fredrikson Intersection	Unknown	circa 40s	None			IIb Supplement
Combat Training Area 2	Estey Road at Powerline Corridor	Unknown	circa 40s	None			IIb Supplement
Combat Training Area 3	At Pew Rd and Connery Ave. Intersection	Unknown	circa 40s	None			IIb Supplement
Former Infiltration Courses	Wheelock and Frank Perkins Rd Intersection near Pocasset-Sandwich Rd	D & MG	40s	Current MP-4 Current L Range	M G	90s 80s-90s	IIb Supplement
Latrines	Various locations	None	40s-90s	None			IIb Supplement
TA A-I	Estey, Pew, Connery, & Fredrikson	SA, S, and P					IIb Supplement
TA A-2	Estey, Frank Perkins, Herbert, & Pew	SA, S, and P					IIb Supplement
TA A-3	Pocasset-Forestdale, Pew, Estey, & Fredrikson	SA, S, and P					IIb Supplement
TA-A-4	Pocasset-Forestdale, Frank Perkins, Estey, & Pew	SA, S, and P					TA Workplan
TA A-5	Wheelock, Pew, & Pocasset-Forestdale	SA, S, and P					TA Workplan
TA A-6	Frank Perkins & Wheellock	SA, S, and P					TA Workplan
TA B-7	Monument, Burgoyne Road, & Frank Perkins	SA, S, and P					TA Workplan
TA B-8	Wood, Burgoyne, & Monument Beach	SA, S, and P					TA Workplan
TA B-9	Hendrick, Orchard, Wood, & Canalview	SA, S, and P					IIb Supplement

Table 2-3

Camp Edwards Training Areas and Ranges
Feasibility Study Work Plan

Designation	Location	Training Activities	Date of Usage	Other Range Designation`	Training Activities	Date of Usage	Workplan Phase
TA B-10	Orchard, Gibbs, & Burgoyne	SA, S, and P					IIb Supplement
TA B-11	Gibbs, Orchard, Hendrick, & Canalview	SA, S, and P					IIb Supplement
TA B-12	Gibbs & Abbey	SA, S, and P					TA Workplan
TA C-13	Route 6, North Avery, Gibbs, & Cat	SA, S, and P					TA Workplan
TA C-14	Route 6, Spruce Swamp, Gibbs, & North Avery	SA, S, and P					TA Workplan
TA C-15	Route 6, Spruce Swamp, Gibbs Road, & Barlow	SA, S, and P					TA Workplan
TA C-16	Gibbs & Barlow	SA, S, and P					TA Workplan
TA BA-1	Howe, Turpentine, Herbert, & Frank Perkins	SA, S, and P					IIb
TA BA-2	Connery, Turpentine, &	SA, S, and P					IIb Supplement
TA BA-3	Pew & Frank Perkins	SA, S, and P					IIb Supplement
TA BA-4	Frank Perkins, Pocasset-Forestdale, & Pew	SA. S, and P					IIb Supplement
TA BA-5	Gibbs & Greenway	SA, S, and P					IIb Supplement
TA BA-6	Pocasset-Forestdale & Turpentine	SA, S, and P					IIb Supplement

A - Artillery
B - Bazooka
D-Demolition Area
DOD-Dept. of Defense
F-firework
G- Grenade
GP- Gun Position
HE- High Explosive
M- Mortar
MG- Machine Gun
P- Pyrotechnics
PR- Propellants
R- Rocket
S- Smoke
SA- Small Arms
SG- Shot Gun
TA- Training Area

Table 2-4
Surface Clearance UXO Discoveries
Feasibility Study Work Plan

Phase II Study Area Surveyd	Landmark	Size (sq ft)	Ordnance Type	Quantity Found
Gun Position 1 (old)	Grid A-N -14	6,776		
Gun Position 2	Grid A-N -14	6,776		
Gun Position 2 (old) Along Herbert Road	Grid A-Q -17	8,228		
Gun Position 3 (old) Along Herbert Road	Grid A-T -20	9,680		
Gun Position 3 (old) Along Howe Road	Grid A-F -6	2,904		
Gun Position 4 (old) Along Howe Road	Grid A-I -9	4,356		
Gun Position 4 (old) Off of Turpentine Road	Grid A-H -8	3,872		
Gun Position 5	Grid A -1	484		
Gun Position 6	Grid A-H. MW-64 -8	3,872		
Gun Position 8	Grid A-G -7	3,388		
Gun Position 10	Grid A-I -9	4,356		
Gun Position 11	Grid A-J -10	4,840		
Gun Position 12	Grid A-C -3	1,452		
Gun Position 14	Grid A-C. MW-65 -3	1,452		
Gun Position 15 (old)	Grid A-I. MW-20&32 -9	4,356		
Gun Position 17	Grid A-B -2	968		
Gun Position 19 (old)	Grid A-R -18	8,712		
Gun Position 20	Grid A-F. MW-67 -6	2,904		
Gun Position 22	Grid A-E -5	2,420		
Gun Position 24	Grid A-G -7	3,388		
Mortar Position 1	Grid A-B MW-68 -2	968		
Mortar Position 1 (old)	Grid A-B -2	968		
Mortar Position 2	Grid A-B -2	968		
Mortar Position 2 (old)	Grid A-R -18	8,712		
Mortar Position 3 (old)	Grid A -1	484		
Mortar Position 4	Grid A-D MW-70 -4	1,936		
Mortar Position 7	Grid A-C MW-71 -3	1,452		
Mortar Position 9	Grid A -1	484		
Mortar Positions at old H Range	Grid A-Q -17	8,228		
F Range	Grid A-Q 03WT0021&03MW0707 -17	8,228		
	Total Grids=243			
Target 1	Buoy MW-1 -20'R	1,258		
Target 2	Not Found			
Target 3	Tank. MW-25 -25'R	1,966		
Target 4	APC. MW-25 -20'R	1,258		
Target 5	Buoy. MW-25 -20'R	1,258		
Target 6	APC. -20'R	1,258		
Target 7	APC. -20'R	1,258		
Target 8	Not Observed			
Target 9	Buoy PMT2 -20'R	1,258		
Target 10	Buoy. PMT2 -20'R	1,258		
Target 11	APC PMT2 -20'R	1,258		
	Total Targets=9			
Ground Scar 7 (around buoy. 20'R)		1,258		
Ground Scar 8 (2 grids. 22'x22')	Grid A-B -2	968		
Ground Scar 9 (6 grids. 22'x22')	Grid A-F -6	2,904		
Pit 1 (2 grids. 22'x22')	Grid V-W -2	968		
Excavation 2 (3 grids. 22'x22')	Grid A-C -3	1,452		
Bunker 1 (CS-19) (3 grids. 22'x22')	Grid A-C -3	1,452		
	Total Grids=16 Total Targets=1			
Total Area Surveyed		138,647		

Table 2-4 (continued)
Surface Clearance UXO Discoveries
Feasibility Study Work Plan

Phase I Study Area Surveyd	Landmark	Size (sq ft)	Ordnance Type	Quantity Found
1	MW-3	9,000		
2	MW-2 & MW-26	59,600		
3	MW-1	15,000		
4	MW-27	7,650		
6	MW-7	15,000		
7	MW-8	13,800		
8	Sueconsette Pond	13,860	2.36" rocket HEAT	1
11	MW-25	33,480		
12	MW-19	4,500		
13	MW-16	6,550		
14	Control	4,500		
15	Site 6	1,800		
16	GP-16	10,800		
17	GP-7	10,800		
18	GP-18	7,200		
19	MP-8	2,700	40mm M918 Training	1
20	MP-6	2,100		
21	MP-3, MP-5	9,000		
22	OP-5,6,7	4,500		
	Tank Alley Grids	33,075		
	Turpentine Road Grids	5,580		
Total Area Surveyed		270,495		

Table 2-5
Intrusive Clearance UXO Discoveries
Feasibility Study Work Plan

Phase II Study Area	Landmark	Size (sq ft)	Ordnance Type	Quantity Found	Density (rnds/acre)
	Target 4/MW-25	NA	37mm HE	1	
	MW-31	10,000			
	MW-32	10,000			
	MW-33	10,000			
	MW-34	13,450			
	MW-35	10,000			
	MW-36	15,175			
	MW-37	16.038	4.2' mortar HE	1	13.58
	MW-37		105mm	1	
	MW-37		Smoke Cannister	1	
	MW-37		Smoke Cannister	1	
	MW-37		37mm W38 Practice Fuse	1	
	MW-38	10,000	81mm	1	4.36
	MW-39	10,000	81mm mortar HE	1	4.36
	MW-40	12,588	105mm	2	13.84
	MW-40		155mm HE	2	
	MW-41	10,000			
	MW-42	10,000			
	MW-43	10,000			
	MW-44	18,625			
	MW-45	10,000			
	MW-46	10,000			
	MW-47	10,000			
	MW-48	12,588			
	MW-49	12,588			
	MW-50	10,000			
	MW-51	10,000			
	MW-52	18,625			
	MW-53	15,175			
	MW-54	10,000			
	MW-55	13,450			
	MW-56	10,000			
	MW-57	10,863			
	MW-58	10,000	81mm HE	2	8.71
	MW-59	14,313			
	MW-60	60,025			
	MW-61	10,000			
	MW-62	11,725			
	MW-63	13,450			
	MW-64	10,000			
	MW-65	10,000			
	MW-66	10,000			
	MW-67	16,038			
	MW-68	10,000			
	MW-69	10,000			
	MW-70	10,863			
	MW-71	16,900			
	MW-72	14,313			
	MW-73	10,000			
	MW-74	10,863			
	MW-75	10,863			
	MW-76	10,863			
	MW-77	10,863			

Table 2-5 (continued)
Intrusive Clearance UXO Discoveries
Feasibility Study Work Plan

hase II Study Area	Landmark	Size (sq ft)	Ordnance Type	Quantity Found	Density (rnds/acre)
	MW-78	16,038			
	MW-79	10,000			
	MW-80	10,000			
	MW-81	10,000			
	MW-82	10,000			
	MW-83	10,000			
	MW-84	10,000			
	MW-85	NA			
	MW-86	NA			
	MW-87	NA			
	MW-88	NA			
	APC (N of MW-1.Near Debris Pile)		6in HE	1	
	Avery Rd (MW-42)		37mm	7	
	CS-19		105mm HE	1	
	CS-19		155mm HE	1	
	CS-19		155 LITR	1	
	CS-19		M9A1 Riflegrenade	4	
	Debris Pile (Near APC)		35mm Practic Rocket	2	
	Debris Pile (Near APC)		8" Naval Projectile -Not HE	1	
	Debris Pile (Near APC)		7" Naval Projectile -Not HE	2	
	Debris Pile (Near APC)		175mm Projectile -Not HE	2	
	Debris Pile (Near APC)		6" Projectile (Non-standard Design) -Not HE	1	
	Debris Pile (Near APC)		3.5" Rocket HEAT (Complete Round) -Not HE	122	
	Debris Pile (Near APC)		3.5" Rocket HEAT (Warheads Only) -Not HE	45	
	Demolition Area 1		3.5" M28 Rocket HE	1	
	Demolition Area 1		3.5" M28 Rocket HE	1	
	Demolition Area 1		Partial Flare Casing	1	
	Demolition Area 1		Explosive Compound C-4	4	
	Demolition Area 1		3.5" Rocket HE	1	
	Demolition Area 1		35mm HE	1	
	J-1 Range		60mm Mortar WP	1	
	P-9/MW-85	10,000	4.2" mortar HE	1	17.42
	P-9		4.2" Mortar HE	1	
	P-9		81mm HE	1	
	P-9		155mm Projectile HE	1	
	Tank Alley Rd	10,350	81mm Mortar HE (Determined Inert after BIP)	10	
	Tank Alley Steel Pit (J-1 Range)	62,100	81mm	1	0.70
	Tank Alley UXO Pit (J-1 Range)		80mm	1	
	Target 9	NA	4.2" mortar HE	1	
	Turpentine Rd	43,125	81mm HE	2	2.02
	Total Area Surveyed	801,857			

Phase I Study Area					
1	MW-3	59,650	155mm ejection	1	0.73
2	MW-2 & MW-26	30,000	155mm ejection	2	10.16
2	MW-2 & MW-26		155mm projectile HE	2	
2	MW-2 & MW-26		105mm projectile HE	1	
[illegible]	MW-2 & MW-26		81mm mortar HE	1	
2	MW-2 & MW-26		81mm mortar illumination	1	
2	MW-2 & MW-26		2.25" Training Rockets (Inert)	200+	
3	MW-1	24,000	105mm projectile HE	2	3.63

Table 2-5 (continued)
Intrusive Clearance UXO Discoveries
Feasibility Study Work Plan

Phase I Study Area	Landmark	Size (sq ft)	Ordnance Type	Quantity Found	Density (rnds/acre)
4	MW-27	13,650	105MM projectile HEAT	3	12.76
4	MW-27		105MM projectile HE	1	
5	J Range	9,950	81mm mortar HE	1067	
5	J Range		81mm mortar illumination	4	
5	J Range		60mm mortar spotting	57	
5	J Range		105mm projectile HE	2	
5	J Range		105mm projectile HEAT	2	
5	J Range		M52 series PD fuses	134	
6	MW-7	34,000			
7	MW-8	38,050			
9	MW-4	11,250			
10	MW-5	62,500			
11	MW-25	19,710			
12	MW-19	26,250	30mm projectile HE	3	6.64
12	MW-19		3.5" rocket	1	
13	MW-16	26,250			
13	MW-6	11,250	105mm projectile HEAT	4	30.98
13	MW-6		105mm projectile HE	1	
13	MW-6		81mm mortar HE	1	
13	MW-6		60mm mortar	2	
	MW-9	11,250			
	MW-11	11,250			
	MW-12	11,250			
	MW-13	11,250			
	MW-14	9,750			
	MW-15	11,250			
	MW-28	11,250			
	MW-29	11,250			
	Stormwater	250			
	Tank Alley	31,680			
	Turpentine Rd. & decon. Pad	87,360	81mm mortar HE	2	1.99
	Turpentine Rd. & decon. Pad		60mm mortar HE	2	
	Spruce Swamp Rd.	39,600	2" mortar HE	4	5.50
	Spruce Swamp Rd.		60mm mortar HE	1	
	Pocasset/Sandwich Rd.	146,520	105mm projectile WP	1	0.59
	Pocasset/Sandwich Rd.		4.2" mortar illumination	1	
	Wheelock Rd.	114,210			
	Jefferson Rd.	87,120			
	Chadwick Rd.	55,440			
	Barlow Rd.	153,780			
	Wood Rd.	118,800			
	Indian Trail Rd.	47,520	81mm mortar HE	2	3.67
	Indian Trail Rd.		4.5" Hedge Hog rocket HE	2	
	Total Area Surveyed	1,337,290			

Table 5-1

Potential Soil Remedial Technologies
Feasibility Study Work Plan

Ex-Situ Soil Alternatives	In-Situ Soil Alternatives
• No Action • Off-Site Landfill Disposal • Composting • Biotreatment • White Rot Fungus • Incineration • Low Temperature Thermal Desorption	• No Action • Landfarming • Thermal Blanket • Electrokinetics • Deep Soil Mixing • Soil Flushing • Phytoremediation • Capping

Table 5-2

Potential Groundwater Remedial Technologies
Feasibility Study Work Plan

Ex-Situ Groundwater Alternatives	In-Situ Groundwater Alternatives
• No Action	• No Action
• Hydraulic Containment	• Impermeable Barrier Wall
- Carbon Treatment	• Reactive Barrier Wall
- BioReactor Treatment	• Recirculation Well
- Zero-Valent Iron Treatment	• Chemical Oxidation
- Catalytic Oxidation Treatment	• Monitored Natural Attenuation
- Ultraviolet Oxidation Treatment	

Table 5-3

Feasibility Study Data Requirements
Potential Soil Remedial Technologies
Feasibility Study Work Plan

Potential Remedial Technology	Data Needed[1]								
	Bench/Pilot Studies	Soil Moisture	Grain Size / Hydraulic Conductivity	pH	Desorption Kinetics	Osmotic Permeability	Electrical Conductivity	Thermal Parameters[2]	Waste Classification[3]
No Action									
Off-Site Landfill Disposal									✓
Biotreatment (including composting, white rot fungus & land farming)	✓	✓	✓	✓					
Incineration		✓	✓					✓	✓
Low Temp Thermal Desorption		✓	✓					✓	✓
Thermal Blanket	✓	✓							
Electrokinetics	✓	✓	✓	✓		✓	✓		
Deep Soil Mixing	✓			✓					
Soil Flushing	✓		✓	✓					
Phytoremediation	✓	✓		✓	✓				
Capping		✓	✓						

Footnotes:

[1] This table lists preliminary data requirements. More detailed and alternative specific feasibility study data requirements may be determined during the initial screening and reported in the Post-Screening Investigation Work Plan.

[2] Thermal parameters, depending on the technology/facility, typically include: heating value of waste; halogens; oversized; parameters restricted by permit (e.g., PCBs, cyanide, pentachlorophenol).

[3] Waste classification parameters for soil include, depending on certification: toxicity characteristic leaching procedure (TCLP), cyanide reactivity, sulfur reactivity and corrosivity. Waste classification also requires consideration of potential land disposal restrictions.

Table 5-4

Summary of Existing Soil Treatability Data
Feasibility Study Work Plan

Analyte	Units	# Samples Collected	Sample ID Maximum	Maximum Concentration	Data Flags	Average
Central Impact Area						
Moisture Content	PERCENT	40	HC11G1AAA	23.1	*	16.1
Total Organic Carbon (TOC)	MG/KG	38	HC11G1AAA	59100		17076.5
Demolition Area 1						
Moisture Content	PERCENT	8	HC12J1BAA	19.1	*	12.3

Notes:

1.) A database query for soil data collected to date at the Central Impact Area, Demolition Area 1 and the Southeast Corner of the Ranges was performed to compile this table. The Southeast Corner of the Ranges is not listed since this information has not yet been obtained.

2.) *Moisture content is not a validated parameter.

Table 5-5

Feasibility Study Data Requirements
Potential Groundwater Remedial Alternatives
Feasibility Study Work Plan

Potential Alternative	Data Needed[1]				
	Bench/Pilot Studies	Hydraulic Conductivity	Grain Size	pH	Biological Parameters[2]
No Action					
Hydraulic Containment		✓		✓	✓
Impermeable Barrier Wall		✓	✓	✓	
Reactive Barrier Wall	✓	✓	✓	✓	✓
Recirculation Well	✓	✓	✓	✓	✓
Chemical Oxidation	✓	✓		✓	✓
Monitored Natural Attenuation	✓	✓		✓	✓

Footnotes:

[1] This table lists preliminary data requirements. More detailed and alternative specific feasibility study data requirements may be determined during the initial screening and reported in the Post-Screening Investigation Work Plan.

[2] Biological parameters, which can also be used to evaluate the potential for fouling problems depending on the technology, typically include: dissolved oxygen, oxidation reduction potential (ORP), nitrate/nitrite, phosphate, sulfate/sulfide, total and dissolved iron and manganese, methane, carbon dioxide, temperature, pH, conductivity, hardness, alkalinity, ammonia-nitrogen, biological oxygen demand (BOD), chemical oxygen demand (COD), and total suspended solids (TSS).

Table 5-6

Summary of Existing Groundwater Treatability Data
Feasibility Study Work Plan

Parameter	Units	# Samples Collected	Location ID. Of Max. Detect	Max.Conc.	Data Flags	Average
Central Impact Area						
Alkalinity, Bicarbonate (as $CaCO_3$)	mg/L	239	W02SSA	51		8.4
Alkalinity, Carbonate (as $CaCO_3$)	mg/L	239	No Detects	-		-
Alkalinity, Hydroxide (as $CaCO_3$)	mg/L	239	No Detects	-		-
Alkalinity, Total (as $CaCO_3$)	mg/L	239	W02SSA	51		8.4
Hardness (as $CaCO_3$)	mg/L	292	W07M1A	151		57.8
Calcium	ug/L	243	W07M1A	19,300		2,697.3
Iron	ug/L	243	W07M1A	102,000		3,006.5
Manganese	ug/L	243	W07M1A	4,070		102.2
Total Organic Carbon	mg/L	239	W02SSA	2.2	J	0.8
Colormetric Dissolved Oxygen	ppm	26	WL37M1	12		9.2
Conductivitiy	us/cm	26	WL51M3	129		72.0
Dissolved Oxygen	ppm	26	WL04	19.05		11.0
Oxygen Reduction Potential	mV	26	WL09	283.3		210.6
pH	-	26	WL51D	6.28		5.5
Temperature	C	26	WL08	15.39		11.1
Turbidity	NTU	26	WL51M1	15.3		2.1
Demolition Area 1						
Alkalinity, Bicarbonate (as $CaCO_3$)	mg/L	20	W19DDA	38		9.38
Alkalinity, Carbonate (as $CaCO_3$)	mg/L	20	No Detects	-		-
Alkalinity, Hydroxide (as $CaCO_3$)	mg/L	20	No Detects	-		-
Alkalinity, Total (as $CaCO_3$)	mg/L	20	W19DDA	38		9.38
Hardness (as $CaCO_3$)	mg/L	27	No Detects	-		-
Calcium	ug/L	25	W19DDA	10,000		3,599.2
Iron	ug/L	25	W19DDA	2,060		1,152.2
Manganese	ug/L	25	W19SSL	465		58.2
Total Organic Carbon	mg/L	20	W19SSA	1.3	J	0.75
Colormetric Dissolved Oxygen	ppm	45	WL33M	49		9.1
Conductivitiy	us/cm	53	WL35S	90123		3,813.1
Dissolved Oxygen	ppm	53	WL33M	18.23		9.0
Oxygen Reduction Potential	mV	53	WL32D	313.5		201.9
pH	-	52	WL19D	7.54		5.7
Temperature	C	53	WL32S	19.98		11.0
Turbidity	NTU	52	WL19D	70		3.2

Table 5-6 (cont.)

Summary of Existing Groundwater Treatability Data
Feasibility Study Work Plan

Parameter	Units	# Samples Collected	Location ID. Of Max. Detect	Max.Conc.	Data Flags	Average
SE Corner of the Ranges						
Alkalinity, Bicarbonate (as $CaCO_3$)	mg/L	43	WF13XA	74		13.9
Alkalinity, Carbonate (as $CaCO_3$)	mg/L	43	90MW0029B	23		23.0
Alkalinity, Hydroxide (as $CaCO_3$)	mg/L	43	No Detects	-		-
Alkalinity, Total (as $CaCO_3$)	mg/L	43	WF13XA	74		14.5
Hardness (as $CaCO_3$)	mg/L	40	WF13XA	45.7		45.7
Calcium	ug/L	41	90MW0029B	9,590	J	2703.9
Iron	ug/L	41	WF13XA	26,200		7301.6
Manganese	ug/L	41	W45SSA	990		157.0
Total Organic Carbon	mg/L	43	WF13XA	6.6		2.4
Colormetric Dissolved Oxygen	ppm	56	90MW0014	12		7.1
Conductivitiy	us/cm	62	90MW0034	419		105.7
Dissolved Oxygen	ppm	62	WL45M1	25.24		8.3
Oxygen Reduction Potential	mV	62	WL45M2	400		179.9
pH	-	62	90MW0029B	9.85		5.7
Temperature	C	62	90LWA0007	17.22		10.7
Turbidity	NTU	61	90MW0029B	59.8		4.4

Notes:

1.) Alkalinity analyzed using Method 310.1.

2.) Hardness, calcium, iron and manganese analyzed using Method IM40B.

3.) Dissolved Oxygen, conductivity, oxygen reduction potential, pH, temperature and turbididity are field measurement parameters.

4.) J - estimated result.

5.) mg/L - milligram per liter
ug/L - micrograms per liter
PPM - parts per million
uS/cm - microsiemen per centimeter
MV - millivolts
C - degrees celsius
NTU - nephelometric turbidity units

Table 8-1

Remedial Design and Remedial Action Submittal Schedule
Feasibility Study Work Plan

Activity	**Due Date (calendar days)**
Draft RD Work Plan and revised POP	60 days after USEPA approval of the selected Remedial Alternative
Final RD Work Plan and revised POP	60 days after receipt of all comments
60% Complete RD	90 days after USEPA approval of Final RD Work Plan
RD In-Progress Review Meetings	Ongoing throughout RD
100% RD	120 days after receipt of USEPA comments on 60% RD
Draft RA Work Plan and revised POP	60 days after USEPA approval of 100% RD
Final RA Work Plan and revised POP	60 days after receipt of all comments
Pre-Construction Conference	15 days after USEPA approval of RA Work Plan
Initiate RA	30 days after USEPA approval of RA Work Plan and POP
Weekly RA Progress Meetings	Ongoing throughout RA
Draft Operation and Maintenance Plan, Environmental Monitoring Plan and revised POP	60 days after 75% construction complete date
Final Operation and Maintenance Plan, Environmental Monitoring Plan and revised POP	60 days after receipt of all comments
Final Construction Inspection	45 days after 100% construction complete
Draft RA or OU Completion Report	60 days after 100% construction complete
Final RA or OU Completion Report	60 days after receipt of all comments
Draft Demonstration of Compliance Report	After demonstrating compliance with established cleanup levels
Final Demonstration of Compliance Report	60 days after receipt of all comments

1. Due dates for submittals correspond with requirements of AO#3.
2. Comment period is anticipated to be 30 to 60 days.
3. Additional submittals/documents beyond those identified may be required.

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